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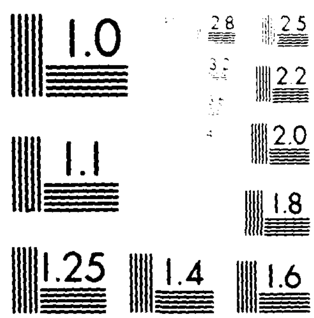

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MISCELLANEOUS PAPER SL-82-5

DETERMINATION OF PROPERTIES OF CONCRETE USED IN THERMAL STUDIES FOR LOCK AND DAM NO. 2, RED RIVER WATERWAY

by

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Two concrete mixtures, one containing and one not containing fly ash, were tested to determine pertinent physical properties for use in a finite element method (FEM) analysis of concrete thermal conditions during the construction of Lock and Dam No. 2 on the Red River Waterway. The overall objective of this testing and analysis was to develop construction procedures aimed at eliminating thermally induced concrete cracking during construction of the structure.

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20. ABSTRACT (Continued).

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The concrete mixtures tested were selected to be representative of those which will be used in the project. Aggregates and cements were from suppliers who could be expected to participate in the actual construction. The testing program included determination of ultimate strain capacity, compressive strength, splitting tensile strength, modulus of elasticity, Poisson's ratio, thermal diffusivity, specific heat, adiabatic temperature rise, and coefficient of linear thermal expansion.

The strain capacity data presented are somewhat unique in that the two concrete mixtures evaluated more closely resembled structural concretes than typical mass concretes.

A limited investigation of the effect of the size of the concrete specimens on their strain capacity was also conducted. Strain capacities were seen to decrease with specimen size for specimens in the range from 18 by 18 by 96 in. to 6 by 6 by 36 in. This decrease may have been the result of one or more of the following: (a) differences in instrumentation used to measure strains; (b) differences in setting and curing termperatures as well as thermally induced strains for the larger beams; and (c) a greater probability of flaws in the larger cross sections of the larger beams.

This report presents and summarizes all data obtained during physical testing of the two concrete mixtures. The FEM thermal analysis will be reported separately.

PREFACE

The investigation described in this report was conducted for the U. S. Army Engineer District, St. Louis, and the U. S. Army Engineer District, New Orleans, by the Concrete Technology Division (CTD) of the Structures Laboratory (SL), U. S. Army Engineer Waterways Experiment Station (WES). Authorization for the investigation was given in DA Forms 2544 dated 2 May 1979 and 15 February 1980.

The investigation was performed under the general supervision of Mr. Bryant Mather, Chief, SL, and Mr. John Scanlon, Chief, CTD; and under the direct supervision of Dr. Tony C. Liu, who served as principal investigator. MAJ Terence C. Holland monitored production of strain capacity specimens and reduced all strain capacity data. Mr. Anthony A. Bombich performed the thermal properties analyses. Mr. Frank Stewart and Mr. Frank Dorsey prepared the concrete mixtures and the strain capacity specimens, respectively. This report was prepared by MAJ Holland.

Funds for the publication of this report were provided from those made available for operation of the Concrete Technology Information Analysis Center (CTIAC). This is CTIAC Report No. 55.

The Commanders and Directors of the WES during this investigation and the preparation and publication of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. Fred R. Brown.

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CONTENTS

CONVERSION FACTORS, INCH-POUND TO METRIC (SI) UNITS OF MEASUREMENT

Inch-pound units of measurement in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
Btu (International Table) per pound (mass) × degree Fahrenheit	4186.8	joules per kilogram Kelvin
Btu (International Table) × foot per hour × square foot × degree Fahrenheit	1.730735	watts per metre Kelvin
calories (International Table) per gram	4186.80	joules per kilogram
cubic feet	0.02831685	cubic metres
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
inches	25.4	millimetres
miles (U. S. statute)	1.609347	kilometres
pounds (force)	4.448222	newtons
pounds (force) per square inch	6894.757	pascals
pounds (force) per square inch per minute	114.91262	pascals per second
pounds (force) per square inch per week	0.114001	pascals per second
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (mass) per cubic yard	0.59328	kilograms per cubic metre
square feet per hour	0.0000258064	square metres per second

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

DETERMINATION OF CONCRETE PROPERTIES USED IN THERMAL STUDIES FOR LOCK AND DAM NO. 2, RED RIVER WATERWAY

PART I: INTRODUCTION

Background

1. Control of thermally induced cracking is an important aspect of mass concrete construction. Unless adequate temperature control measures are implemented, cracks that may have serious consequences during the service life of the structure may develop during construction. However, the cost of temperature control measures may be quite high; therefore, it is unwise to require more control than is actually necessary.

2. To determine the degree of temperature control necessary requires a knowledge of the properties of the concrete to be used as well as a prediction of the temperatures and stresses which may be expected to develop during construction. Both temperature changes created internally (heat of hydration) and externally (weather variations) must be considered. Once temperature predictions have been developed, the strain induced in the concrete may be calculated. Then, the induced strain may be compared to the strain capacity of the concrete to determine if and where cracking may be expected. Based on the outcome of these comparisons, appropriate measures for controlling concrete placement temperature, heat generation, or rate of heat loss may be developed and recommended. Additionally, critical stages during the construction process may be identified and appropriate measures recommended.

Purpose and Scope

3. The purpose of this study was to determine the pertinent properties of two concretes similar to those anticipated to be used during construction of Lock and Dam 2 on the Red River Waterway. Concrete properties investigated were ultimate strain capacity, compressive strength,

splitting tensile strength, modulus of elasticity, Poisson's ratio, thermal diffusivity, specific heat, adiabatic temperature rise, and coefficient of linear thermal expansion. The data developed during this study will be used in a finite element method (FEM) analysis of the thermal considerations associated with the construction of the structure. The FEM study will be reported separately.

4. The determination of strain capacity and elastic properties was conducted in two rounds of testing. With the exception of a slight increase in the number of strain capacity specimens in the second round, the scope of testing was identical for both rounds.

PART II: TESTING PROGRAM AND DATA OBTAINED

Materials

5. The coarse and fine aggregates used (NO-57 G-3 and NO-57 S-3, respectively) were natural materials from a source in the vicinity of the project. Data on the aggregates are presented in Table 1, and a petrographic report is in Appendix A.

6. Because of the presence of chalcedonic chert in the sand and possible presence in the gravel (see petrographic report), Type II low alkali cements were selected for this investigation. The cements selected also met the optional heat of hydration requirement (limit of 70 cal/g* at 7 days) of CRD-C 201-79 (ASTM C 150-78a),** "Standard Specification for Portland Cement." Cements from different manufacturers were used for the two rounds of the investigation. Detailed chemical and physical properties may be found as follows:

Round 1	Cement RC-586	Table 2
Round 2	Cement RC-847	Table 3

7. The pozzolanic material used was a laboratory stock fly ash (AD-590) which is from a source in Georgia. Data on the fly ash are presented in Table 4. This material complied with the applicable portions of CRD-C 255-79 (ASTM C 618-78), "Standard Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete," for a Class F mineral admixture.

8. The air-entraining agent used was a laboratory stock neutralized vinsol resin (AEA-965).

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* A table of factors for converting inch-pound units of measurement to metric (SI) units is presented on page 3.

** All references to CRD-C test methods are from U. S. Army Engineer Waterways Experiment Station, CE, 1949, <u>Handbook for Concrete and Cement</u> (with quarterly supplements), Vicksburg, Miss.

Concrete Mixtures

9. Two concrete mixtures were used during these tests. Mixture A (without pozzolan) was proportioned for a nominal average compressive strength of 3000 psi at 28 days. Mixture B (with a 25 percent by volume pozzolanic replacement) was proportioned for a nominal average compressive strength of 3000 psi at 90 days. Both mixtures contained 5 $\pm$ 1 percent entrained air and both had slumps in the range of 2-1/2 $\pm$ 1/2 in. With the exception of the change in cements noted above, concrete for the two rounds of tests was similar in composition and proportions. Proportions for the two mixtures are given in Tables 5 and 6. These mixtures were somewhat atypical for mass concrete construction due to their high cementitious material contents and their use of 1-1/2-in. maximum sized aggregates. The mixtures were selected on the basis that the contractor ultimately awarded the project could be expected to use the locally available aggregates.

Ultimate Strain Capacity Tests

Test method and schedule

10. Ultimate strain capacity tests were performed in accordance with CRD-C 71-80, "Standard Test Method for Ultimate Strain Capacity of Concrete." Briefly, the procedure was as follows: Concrete specimens for the tests were 12 by 12 by 66 in. and were cast in steel forms. At an average age of 3 days, the specimens were removed from the forms, wrapped in a waterproof material to retain moisture, and tested or stored pending testing as appropriate. Internal strain meters (Carlson meters) were used for both the rapid and slow loading specimens. One meter was embedded in the compression zone of the specimen and one was embedded in the tension zone. Readings for all tests were taken manually using an automatic digital readout device. Rapid loading was accomplished using a 50,000-lb (force) electrohydraulic loading system. The rate of loading was set to cause a 40-psi/min increase in extreme fiber stress. For the rapid loading tests, strain readings were taken at 500-lb (force)

increments. Slow loading was accomplished using hydraulic rams in conjunction with pressure gages. Rams and gages were calibrated in a testing machine to develop a loading equation for each ram. This equation was then used to determine necessary gage pressure to develop the required loads for the desired slow loading rate of 25 psi/week increase in extreme fiber stress. After initial loading, hydraulic pressures were checked daily to maintain the proper loads. For the slow load specimens strain readings were taken on a daily basis.

11. The overall test program is shown in Table 7. Limited testing (rapid only) was accomplished using specimens 1 and 90 days old while complete testing (rapid, slow, and companion rapid) was accomplished using specimens 3, 7, and 28 days old. The test program was identical during both rounds except that an additional 28-day slow load and companion rapid load beam were added for both mixtures during the second round. This was done to compensate for questionable data obtained from the 28-day slow load beams during the first round of testing.

12. Specimens were identified during the testing program (and in the tables which are described below) as follows:

a. Round 1: Mixture, beam number (as per Table 7).
Example: Beam A3: Round 1, Mixture A, 3-day slow load specimen.

b. Round 2: 2, Mixture, beam number (as per Table 7).
Example: Beam 2B6: Round 2, Mixture B, 7-day slow load specimen. A letter following the beam number indicates a duplicate specimen. Example: Beams 2A9A and 2A9B were duplicates tested under the same conditions.

Data reduction and test results

13. Test data were reduced using a locally prepared computer program (Appendix B). Strains measured at the strain meters were extrapolated to the surface fibers of the specimens. Extrapolation was normally accomplished using the tensile and compressive strains as measured at the meters without requiring the neutral axis to lie at the middepth of the beam. The depth of the neutral axis was calculated as a check. If the calculated neutral axis was not close (± 1 in.) to the middepth of the beam or if one of the meters malfunctioned, the neutral axis was assumed to be at middepth and strains were extrapolated on that basis.

Once the extreme fiber strain was determined, a linear regression analysis was performed to relate extreme fiber strain to applied stress.

14. The modulus of rupture was determined for each specimen in accordance with CRD-C 16-79 (ASTM C 78-75), "Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)." The equation produced by the linear regression analysis was used to determine the extreme fiber strain at 90 percent of the modulus of rupture. This strain is reported as the ultimate strain capacity.

15. Data from the ultimate strain capacity tests are presented in Tables 8-14 as follows (comments concerning the data are given in the following subparagraphs):

a. Table 8. Detailed Data, Mixture A, Round 1. The tension strain meter on beam A9 (28-day slow load) malfunctioned. The compressive strain capacity for that beam appears to be very low indicating a possible malfunction.

b. Table 9. Detailed Data, Mixture A, Round 2. Duplicate 28-day slow load and companion rapid load beams were included in this round to compensate for the malfunction which occurred in Round 1. The compression strain meters in all of the slow load specimens in this round malfunctioned; therefore, tensile strain capacity for slow load specimens was extrapolated from meter readings using a fixed neutral axis. The break in beam 2A11 occurred outside the middle third of the beam, necessitating a reduction in the calculated modulus of rupture.

c. Table 10. Detailed Data, Mixture B, Round 1. The tensile strain capacity for beam B9 (28-day slow load) appears to be quite low, and there is a large difference between the compressive and tensile strain capacities.

d. Table 11. Detailed Data, Mixture B, Round 2. Same notes as Table 9.

e. Table 12. Summarized Data, Mixture A, Rapid Load Tests. There appears to be good agreement between the two rounds of testing.

f. Table 13. Summarized Data, Mixture B, Rapid Load Tests. There also appears to be good agreement between the two rounds for Mixture B.

g. Table 14. Summarized Data, Mixtures A and B, Slow Load Tests. Agreement between the two rounds of tests appears to be acceptable. Because of the malfunctions on the compression meters for both Mixtures A and B during Round 2, strain capacities for Round 1 were calculated

using a fixed neutral axis to allow for accurate comparison. Note, however, that there is very little difference between the results obtained using the two extrapolation methods, provided that the tension and compression meters are both functioning properly.

16. The data presented in Tables 12, 13, and 14 were also plotted and are shown in Figures 1, 2, and 3, respectively.

Size effects investigation

17. A limited investigation of the effect of the size of beam tested on the ultimate strain capacity was also conducted. Beams smaller (6 by 6 by 36 in.) than those normally tested (12 by 12 by 66 in.) and beams larger (18 by 18 by 96 in.) than normal were tested under rapid loading conditions. These tests were conducted during both rounds of the test program. Concrete Mixture A was used for all size effects testing.

18. For the small beams (6 by 6 by 36 in.) strains were obtained using strain gages bonded to the concrete surface. For the large beams (18 by 18 by 96 in.) internal strain meters were used, and data reduction was accomplished in the same manner as described above for the normal sized beams. Figure 4 shows one of the large beams before and after loading.

19. Data from the tests of the small and large beams are presented in Table 15. These data show a good general consistency from Round 1 to Round 2. Average values for the small and large beams are compared to average values of normal sized beams (made with the same concrete mixture) in Table 16. The average values for ultimate tensile strain capacity for the three sizes of beams are plotted in Figure 5.

20. With the exception of the 28-day value for the small beams, the size effects data appear to be consistent. The ultimate tensile strain capacity for the small beams at 28 days was low for both rounds of tests. For the first round, the data are believed to be acceptable. For the second round, the low value is believed to be due to problems which were encountered bonding the surface gages to the concrete specimens on the day of testing the 28-day specimens.

Elastic Properties

Compressive and splitting tensile strength

21. Compressive strength testing and splitting tensile strength testing were conducted whenever a rapid load beam was tested or whenever a slow load beam was initially loaded. Compressive strength testing was done in accordance with CRD-C 14-73 (ASTM C 39-80), "Standard Method of Test for Compressive Strength of Cylindrical Concrete Cylinders." Splitting tensile strength testing was done in accordance with CRD-C 77-72 (ASTM C 496-71), "Standard Method of Test for Splitting Tensile Strength of Cylindrical Concrete Specimens."

22. Data for the compressive strength and splitting tensile strength tests are presented in Tables 17 and 18 for mixtures A and B, respectively. Compressive strength and splitting tensile strength data for the two mixtures have been plotted in Figures 6 and 7. The data for both compressive strength and splitting tensile strength show good agreement for the two rounds of testing with the values for the second round being consistently slightly lower than the first round. The difference does not appear to be significant.

Modulus of elasticity and Poisson's Ratio

23. The modulus of elasticity and Poisson's ratio were obtained from cylinders tested for compressive strength at 1, 3, 7, 28, and 90 days. Testing was in accordance with CRD-C 19-75 (ASTM C 469-65), "Standard Method of Test for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression."

24. Modulus of elasticity and Poisson's ratio data for both mixtures are presented in Table 19 and are shown in Figure 8. There appears to be satisfactory agreement between the two rounds of tests.

Thermal Properties

25. The various thermal properties listed in paragraph 3 were determined for Mixture B during this study. (The cement used during

the thermal studies was that used in the second round of ultimate strain capacity tests.) The same thermal properties had been determined earlier for Mixture A during a study in conjunction with the construction of Lock and Dam No. 1 on the Red River Waterway* and were not repeated. Data from that study are presented in this report to allow comparisons with Mixture B. A summary of all thermal properties is presented in Table 20.

26. Thermal diffusivity for Mixture B was determined in accordance with CRD-C 36-73, "Method of Test for Thermal Diffusivity of Con-concrete." Two 6- by 12-in. cylinders, each containing a copper-constantan thermocouple at the centroid, were used for the tests. The average thermal diffusivity of the concrete at 28 days was 0.045 ft^2/hr. The value determined previously for Mixture A was 0.042 ft^2/hr.

27. Specific heat for Mixture B was determined in accordance with CRD-C 124-73, "Method of Test for Specific Heat of Aggregates, Concrete, and Other Materials (Method of Mixtures)." Concrete from the cylinders tested for thermal diffusivity was used for the specific heat tests. The specific heat of Mixture B was determined to be 0.22 Btu/lb $\times$ $^{\circ}F$. The same value was determined earlier for Mixture A.

28. Thermal conductivity for Mixture B was calculated in accordance with CRD-C 44-63, "Method for Calculation of Thermal Conductivity of Concrete," using experimentally derived values for thermal diffusivity, specific heat, and unit weight. The thermal conductivity of Mixture B was 1.38 Btu $\times$ ft/hr $\times$ ft^2 $\times$ $^{\circ}F$. The value determined earlier for Mixture A was 1.32 Btu $\times$ ft/hr $\times$ ft^2 $\times$ $^{\circ}F$.

29. An adiabatic temperature rise test was conducted for mixture B in accordance with CRD-C 38-73, "Method of Test for Temperature Rise in Concrete." The concrete sample used was a 30- by 30-in. cylinder containing five resistance thermometers. The adiabatic temperature rise for Mixture B at 28 days was 64.66°F. The value determined earlier

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* U. S. Army Engineer District, New Orleans, CE. 1977. "Red River Waterway; Design Memorandum No. 8, Lock and Dam No. 1, Sources of Construction Materials," New Orleans, Louisiana.

for Mixture A was 70.07°F. Temperature rise versus age data for both mixtures are in Table 21 and are plotted in Figure 9.

30. The coefficient of linear thermal expansion for Mixture B was not determined directly. Based on earlier studies,* it appears that the inclusion of fly ash, in the proportions used for Mixture B, does not significantly affect linear thermal expansion. Therefore, the value of linear thermal expansion determined earlier for Mixture A, 7.0 millionths/°F, was judged to be also the appropriate value for Mixture B.

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* J. E. McDonald. 1973. "Ultimate Strain Capacity Tests, Clarence Cannon Dam, St. Louis District," Miscellaneous Paper C-73-5, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
J. E. McDonald, A. A. Bombich, and B. R. Sullivan. 1972. "Ultimate Strain Capacity and Temperature Rise Studies, Trumbull Pond Dam," Miscellaneous Paper C-72-20, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

PART III: DISCUSSION

31. The data obtained for elastic and thermal properties of the two concrete mixtures appear to be consistent and suitable for use in further analysis. The use of two different cements during the two rounds of the study should help to insure that values representative of the actual construction conditions were obtained.

32. A lack of test data for similar concretes makes comparison of strain capacity data obtained during the present study with data obtained during earlier work essentially impossible. However, the general performance of the two mixtures evaluated appears to be consistent with that of a wide variety of concrete mixtures evaluated during other investigations. The strain capacity data appear to be suitable for use in cracking predictions.

33. Mixture A showed tensile strain capacities during slow loading which were 1.80, 1.97, and 2.43 times those obtained during rapid loading for tests conducted at 3, 7, and 28 days, respectively. The continued increase in slow loading strain capacity at 28 days is somewhat unusual when compared to earlier tests. Beams tested under rapid loading conditions on the days when failure occurred for companion slow loaded beams showed tensile strain capacities which were 1.11, 1.06, and 1.13 times those seen in initial rapid load tests at 3, 7, and 28 days, respectively.

34. Mixture B showed tensile strain capacities during slow loading which were 2.34, 2.42, and 1.76 times those obtained during rapid loading for tests conducted at 3, 7, and 28 days, respectively. The decrease in slow loading strain capacity at 28 days is consistent with data reported for other projects. Beams tested under rapid loading conditions on the days when failure occurred for companion slow loaded beams showed tensile strain capacities which were 1.38, 1.36, and 1.10 times those seen in initial rapid load tests at 3, 7, and 28 days, respectively.

35. The two mixtures may be compared as follows:

a. Under rapid loading conditions, Mixture A showed greater tensile strain capacities at 3 and 7 days than did Mixture B. For 28 days and beyond rapid loading, there was little difference in tensile strain capacity between the two mixtures.

b. Under slow loading conditions, there was little difference in tensile strain capacity between the mixtures for the tests initiated at 3 and 7 days, although Mixture B showed a much greater ratio of slow to rapid loading tensile strain capacity. For slow load testing initiated at 28 days, Mixture A showed a significantly greater tensile strain capacity than Mixture B.

c. The companion beams tested in rapid loading after a slow loaded beam failed showed very little differences between the two mixtures.

35. Based upon the limited size effect investigation carried out during the present study, measured rapid load tensile strain capacity appears to be affected by the size of the beam tested. Using the data presented in Table 16, the values below may be obtained (based upon the data in the last three rows of Table 16 in which the strains attributable to the dead loads of the various sized beams have been added to the measured strain capacities):

Beam Size, in.	Percent of 6- by 6- by 36-in. Tensile Strain Capacity			
	3 days	7 days	28 days	90 days
6 by 6 by 36	100	100	100	100
12 by 12 by 66	101	85	83	85
18 by 18 by 96	89	72	80	81

These values do show a difference in indicated strain capacity based upon beam size. The differences noted may have been caused by one or more of the following items:

a. Some of the difference may have been due to instrumentation rather than concrete properties since the small beams (6 by 6 in.) were instrumented with surface bonded strain gages while the other two sizes of beams used internal strain meters.

b. The larger beams would have generated a greater amount of heat due to hydration and would have lost that heat more slowly. The temperature under which concrete sets and

cures may influence its strain capacity. Additionally, particularly for the tests at earlier ages, thermal strains may have been present in the larger specimens which reduced measured strain capacities.

c. There was a greater probability of flaws being present in the larger beams due to their larger cross sectional areas.

Regardless of the cause, the differences in strain capacity noted raise the question of which is the appropriate size specimen to use to determine tensile strain capacities for concretes to be used in massive structures. Additional work is needed in this area.

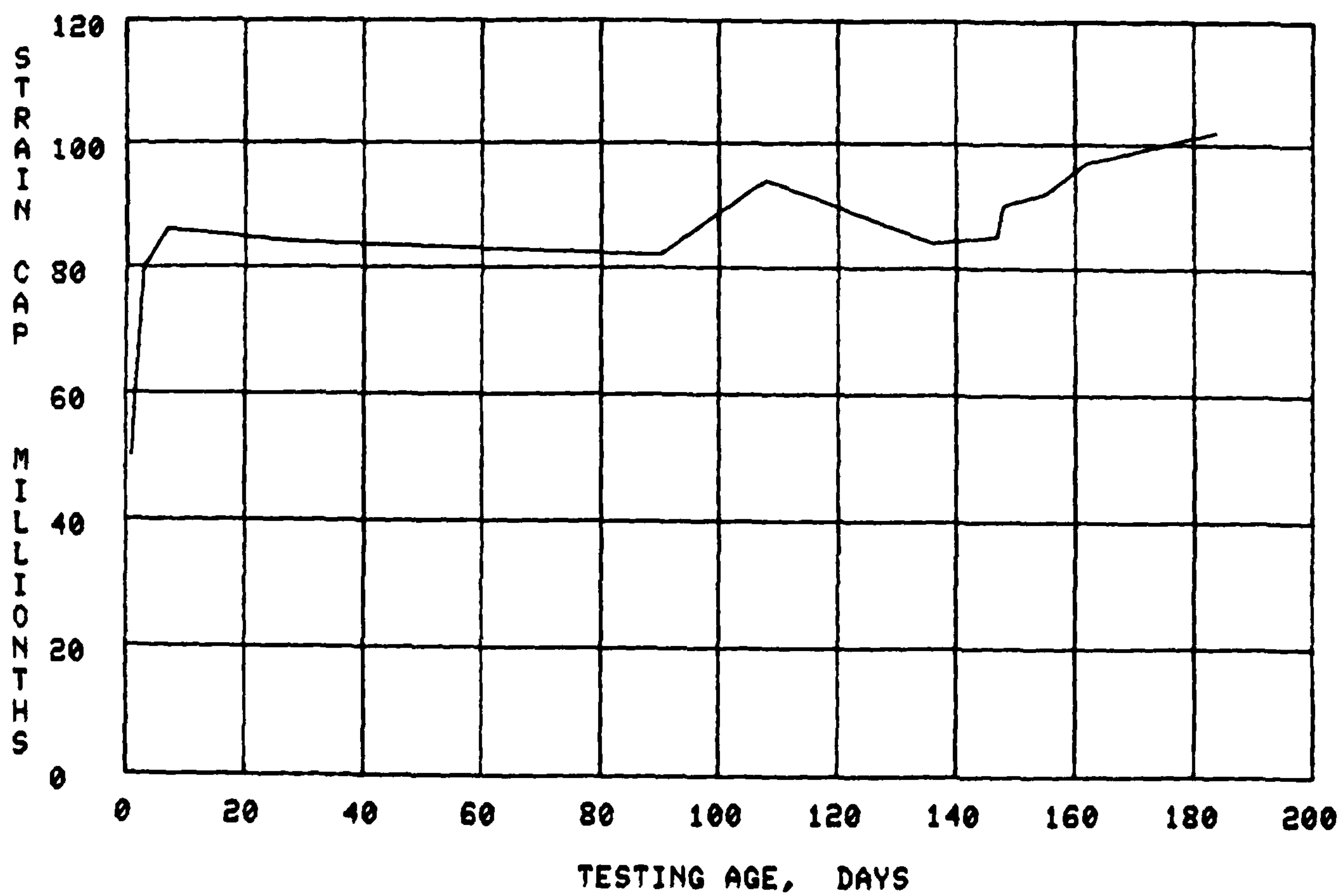


Figure 1. Tensile strain capacity, rapid loading, Mixture A

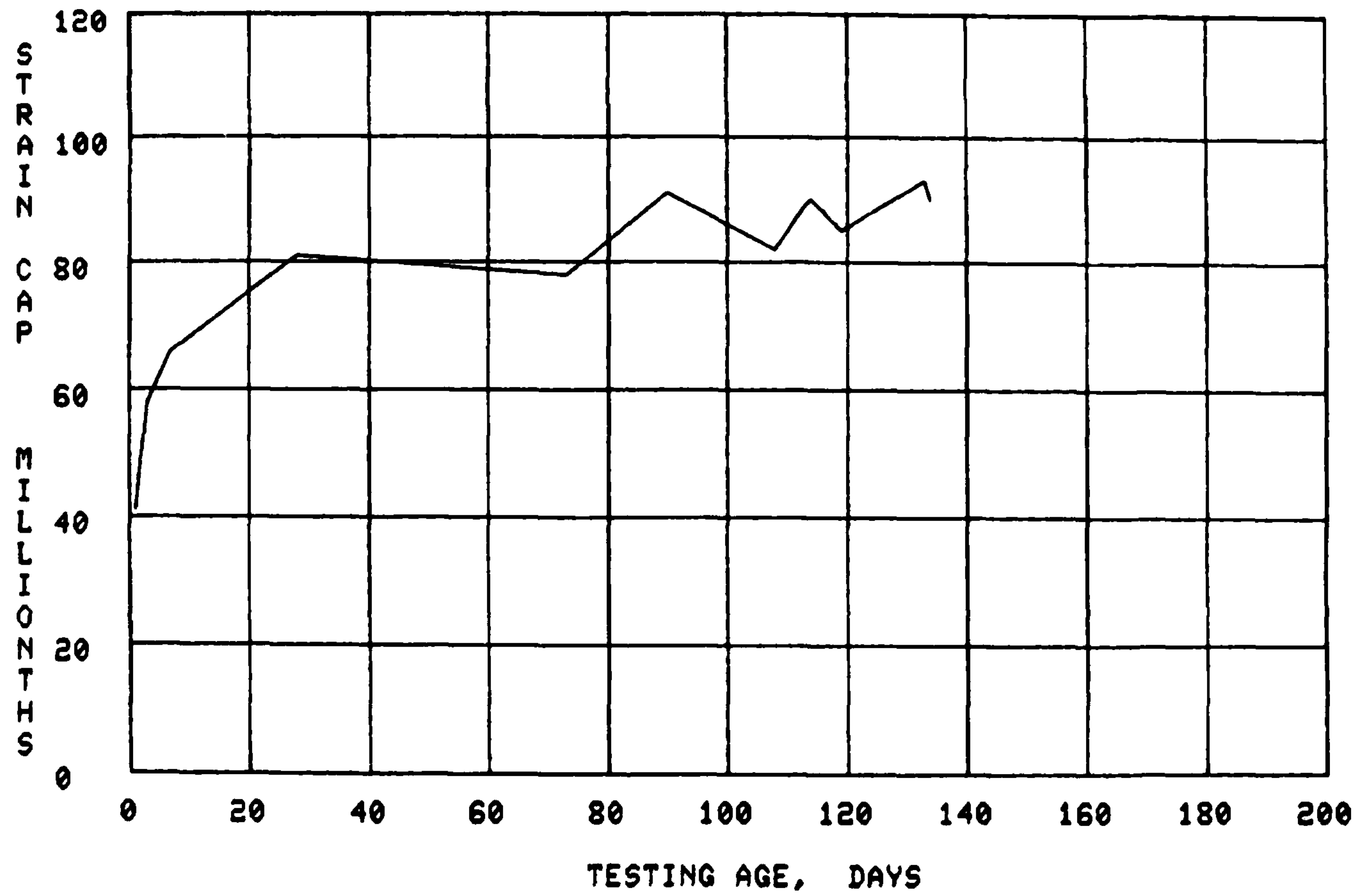


Figure 2. Tensile strain capacity, rapid loading, Mixture B

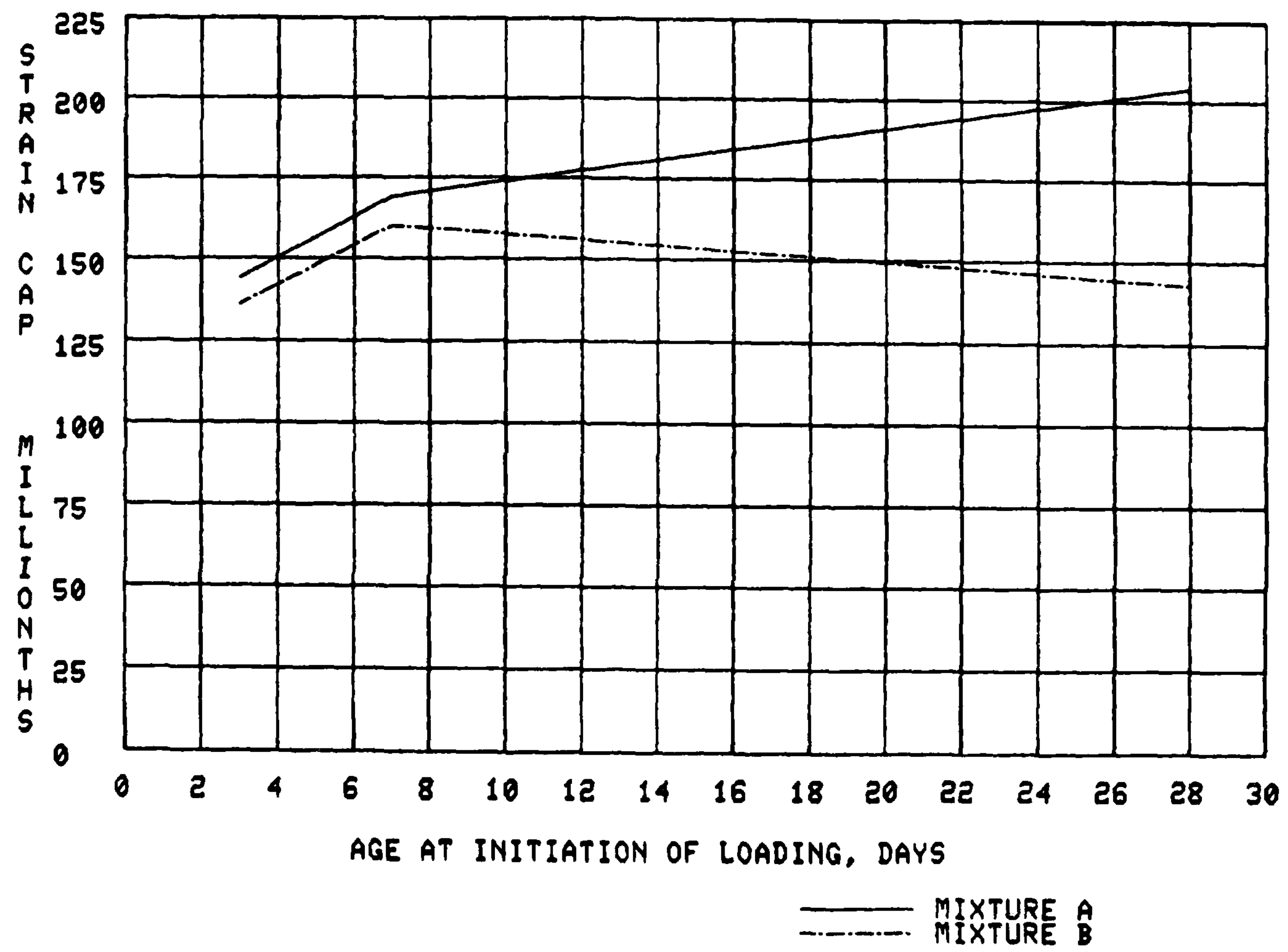
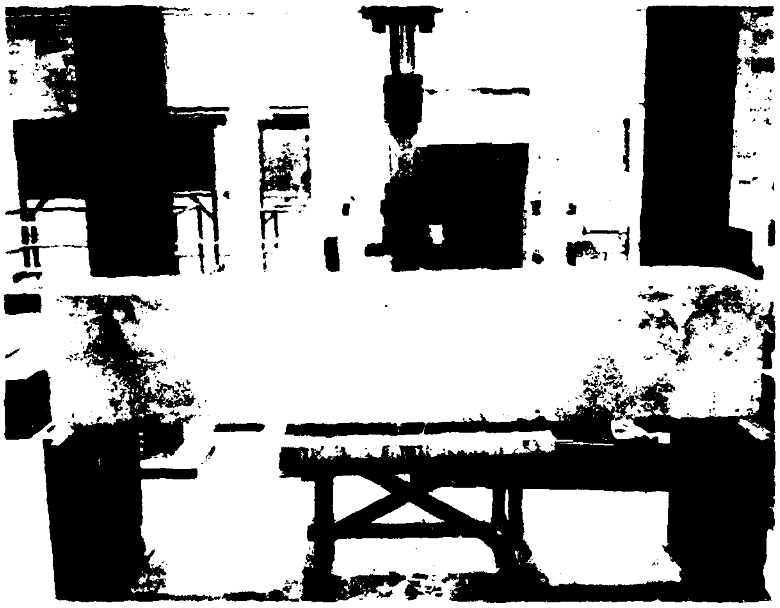
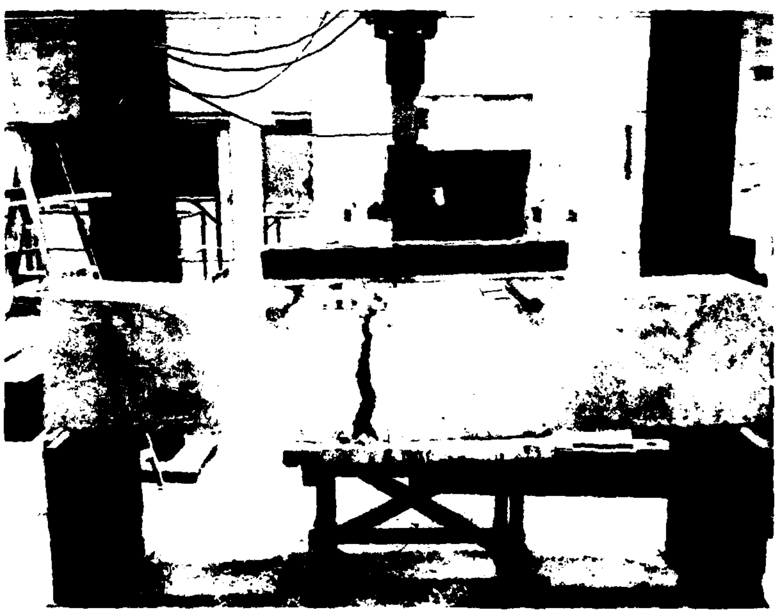


Figure 3. Tensile strain capacity, slow loading, Mixtures A and B



a. Prior to testing



b. After testing

Figure 4. Testing of 18- by 18- by 96-in. beam for ultimate strain capacity

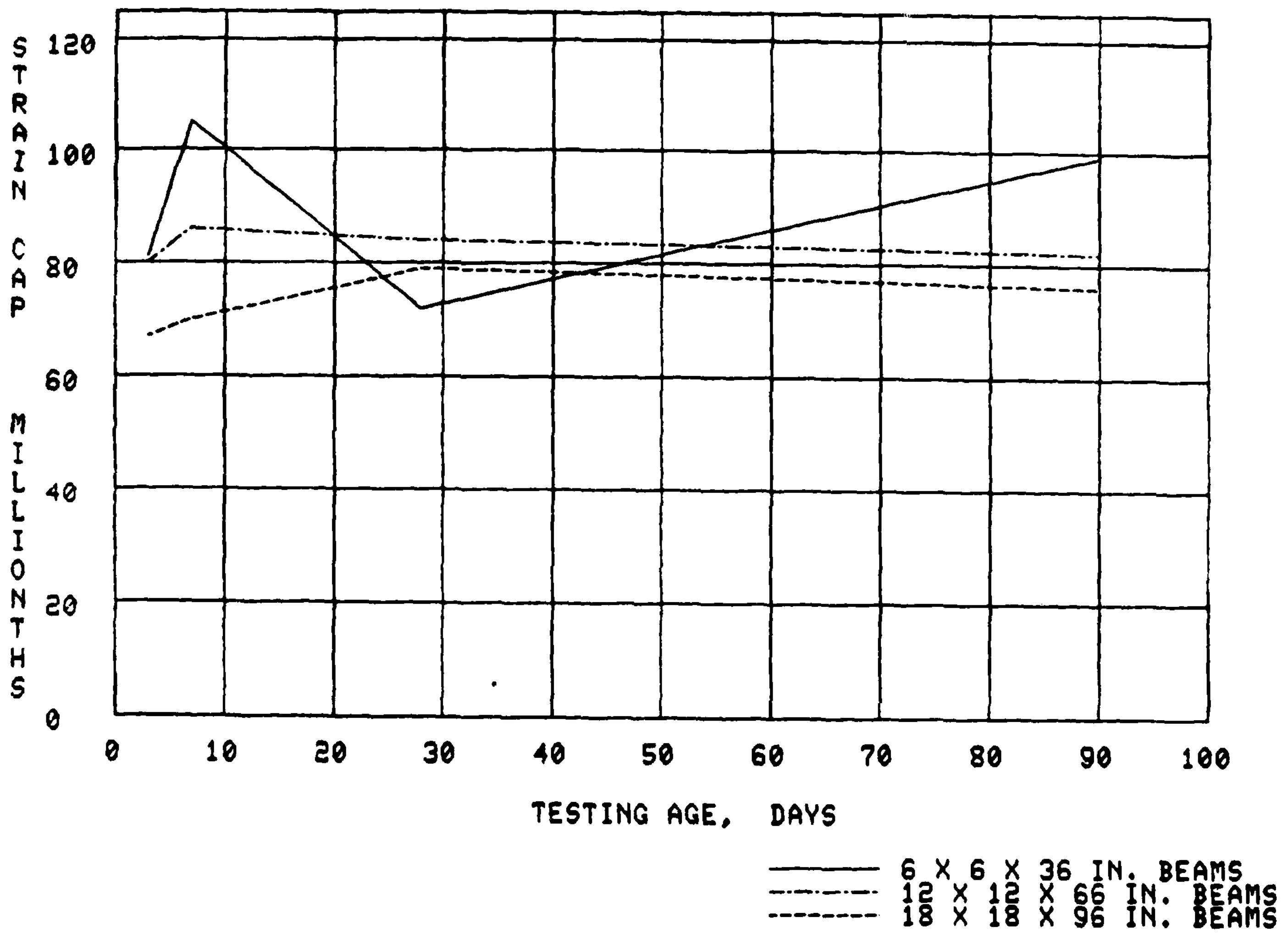


Figure 5. Tensile strain capacity, rapid loading, various sized beams, Mixture A. (Not adjusted for dead load strains)

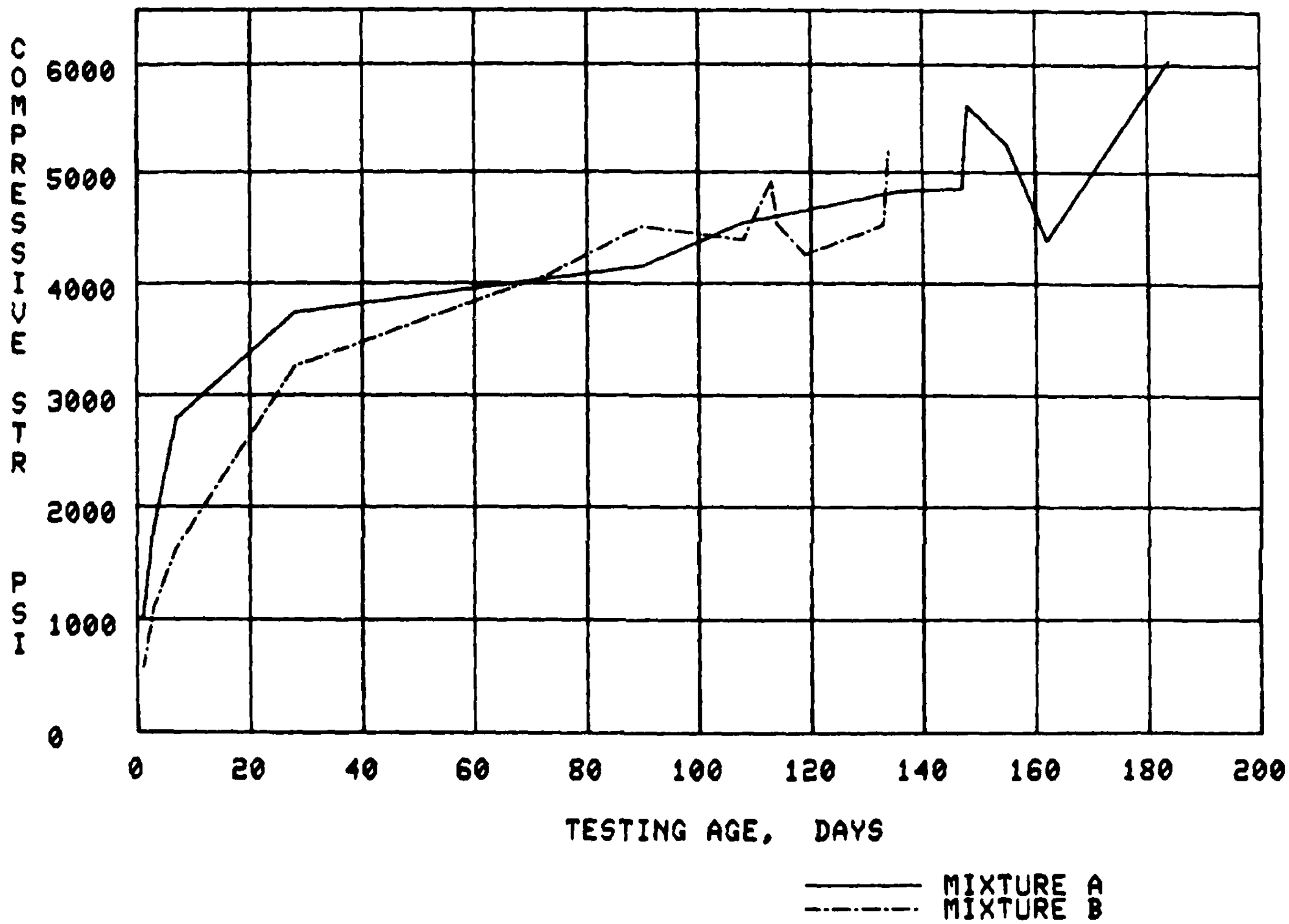


Figure 6. Compressive strength, Mixtures A and B

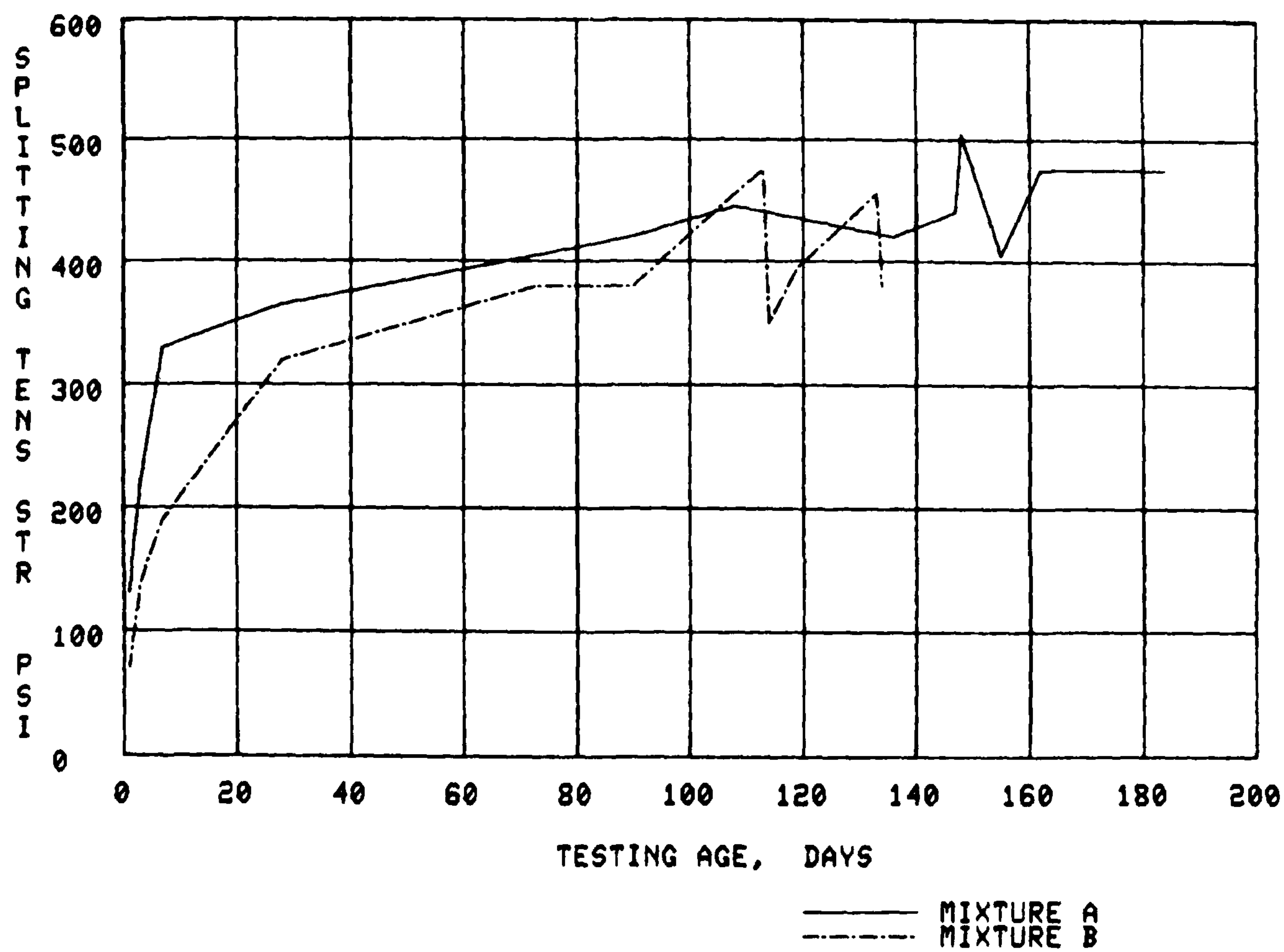


Figure 7. Splitting tensile strength, Mixtures A and B

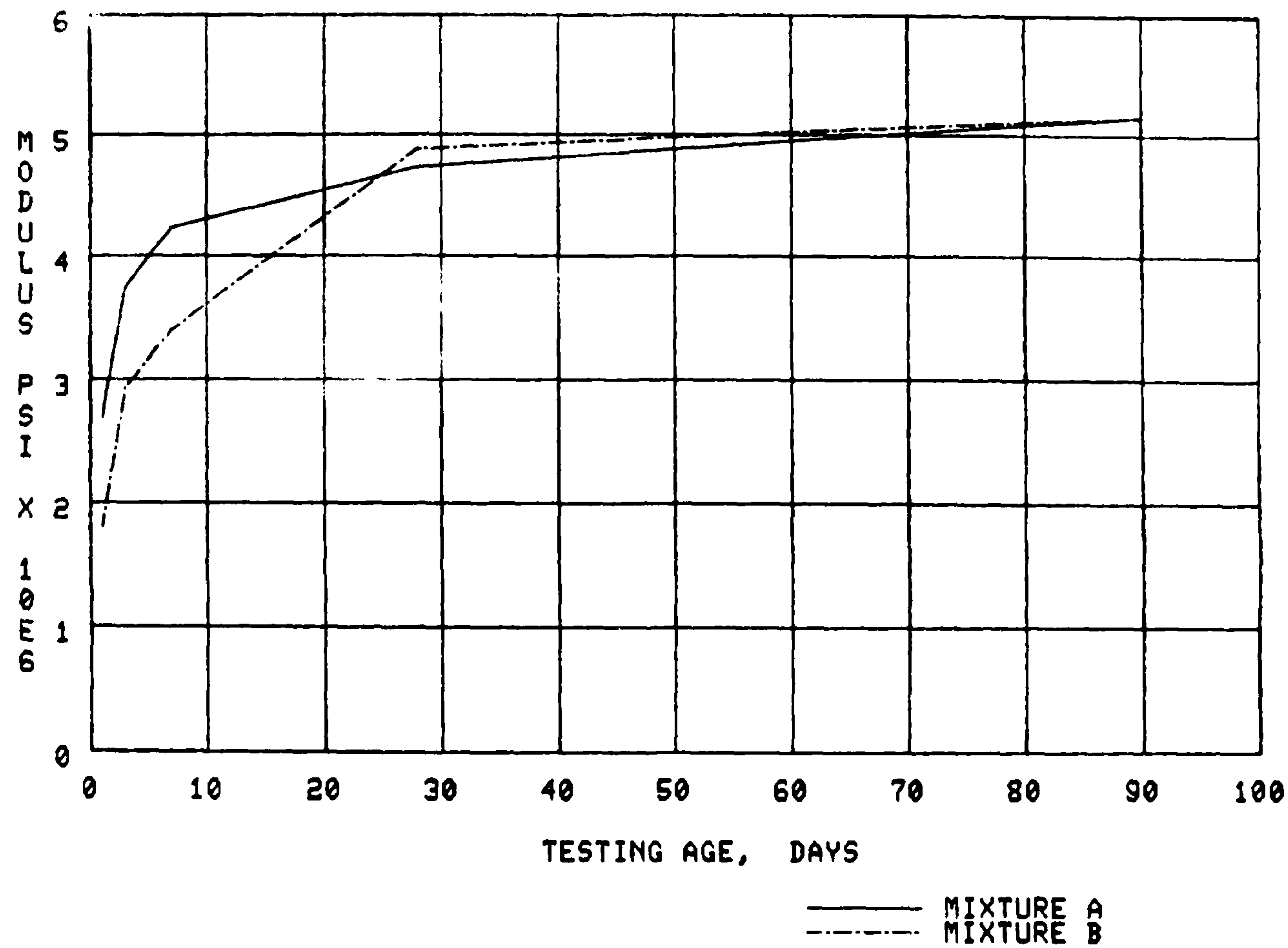


Figure 8. Modulus of elasticity, Mixtures A and B

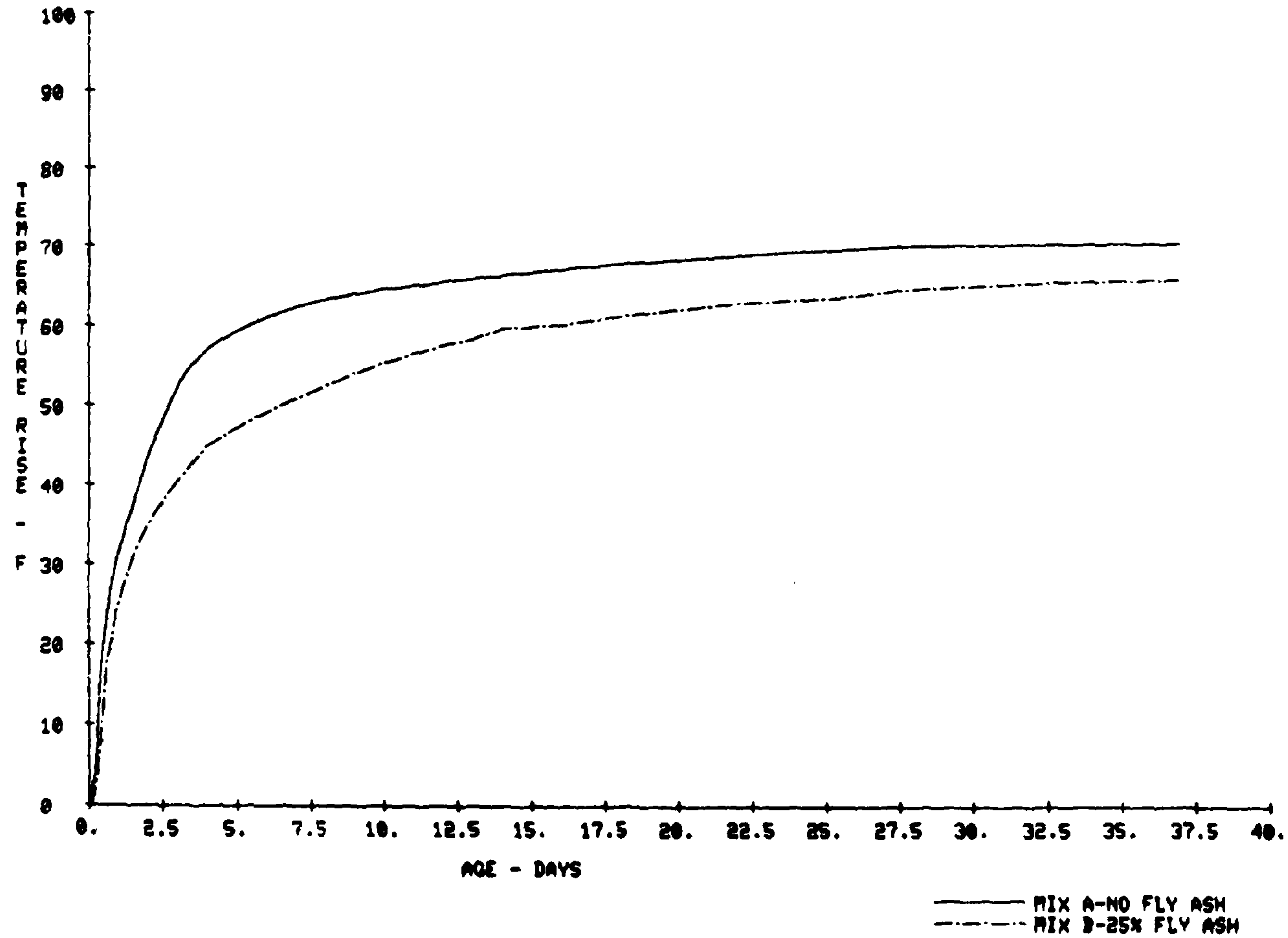


Figure 9. Adiabatic temperature rise, Mixtures A and B

Table 1

Aggregate Data

STATE LA	INDEX NO 17	AGGREGATE DATA SHEET	TESTED BY USAEWES
LAT 31	LONG 92		DATE 7-20-79

LAB SYMBOL NO NO-57 G-3(2) S-3(2) TYPE OF MATERIAL Natural

LOCATION On NE side of Salem Creek, approx. 1.7 miles east of LA 459 and 8.2 miles NE of Jena, LA

PRODUCER Amyx Sand and Gravel, Jena, LA

SAMPLED BY B. Houston, J. Tom, D. Howell, D. Heffner

TESTED FOR Red River L & D No. 2

USED AT

PROCESSING BEFORE TESTING

GEOLOGICAL FORMATION AND AGE Pleistocene Terrace (Willizna) deposit

GRADING (CRD-C 103) (CUM % PASSING)

SIEVE	3-6"	1½-3	¾-1½	#4-¾	FINE AGG.
6 IN					
5 IN					
4 IN					
3 IN					
2½ IN					
2 IN					
1½ IN			100.0		
1 IN			74.0		
¾ IN			40.7	100.0	
½ IN			8.7	72.8	
⅜ IN			4.5	31.6	
NO 4			1.2	2.0	96.7
NO. 8					90.1
NO. 16					80.2
NO 30					43.7
NO 50					7.3
NO 100					0.9
NO. 200					--
-200 (a)					
F.M. (b)					2.81

(a) CRD-C 105 (b) CRD-C 104

TEST RESULTS	3-6"	1½-3	¾-1½	#4-¾	FINE AGG
BULK SP GR S.S.D (CRD-C 107, 108)			2.54	2.54	2.61
ABSORPTION, % (CRD-C 107, 108)			1.07	1.52	0.68
ORGANIC IMPURITIES, FIG. NO (CRD-C 121)	—	—	—	—	*
SOFT PARTICLES, % (CRD-C 130)					—
% LIGHTER THAN SP GR ____ (CRD-C 122)					
% FLAT AND ELONGATED (CRD-C 119, 120)					
WT AV % LOSS, 5 CYC $MgSO_4$ (CRD-C 115)					
L.A. ABRASION LOSS, % (CRD-C 117, 145) GRADING ____					
UNIT WT, LB/CU FT (CRD-C 106)					
FRIABLE PARTICLES, % (CRD-C 142)					
SPEC HEAT, BTU/LB/DEG F (CRD-C 124)					
REACTIVITY WITH NaOH (CRD-C 128) Sc, mM/L					
REACTIVITY WITH NaOH (CRD-C 128) Rc, mM/L					

MORTAR-MAKING PROPERTIES (CRD-C 116)

TYPE ____ CEMENT, RATIO ____ DAYS ____ % ____ DAYS ____ %

LINEAR THERMAL EXPANSION MILLIONTHS DEG F (CRD-C 125, 126)

ROCK TYPE	PARALLEL	ACROSS	ON	AVERAGE

MORTAR

MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123)		FINE AGGREGATE 2 MO.	6 MO	9 MO	12 MO	COARSE AGGREGATE 3 MO	6 MO	9 MO	12 MO
LOW-ALK CEMENT	% Na_2O EQUIVALENT								
HIGH-ALK. CEMENT	% Na_2O EQUIVALENT								

SOUNDNESS IN CONCRETE (CRD-C 40, 114)			F&T	HW-CD	HD-CW
FINE AGG.	COARSE AGG	DFE_{300}			
FINE AGG.	COARSE AGG	DFE_{300}			

PETROGRAPHIC DATA (CRD-C 127)

REMARKS

Table 2

Cement Properties, Round 1

TO		FROM CORPS OF ENGINEERS U. S. ARMY
J. E. McDonald Structures Laboratory Structures Branch Vicksburg, MS	REPORT OF TESTS OF PORTLAND CEMENT RC-586	Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO. WES-216-79 | BIN NO. | WT REPRESENTED | DATE 23 May 79

SPECIFICATION SS-C-1960/3, Type II, LA, HH | DATE SAMPLED 14 May 79

COMPANY Alpha Portland | LOCATION Birmingham, AL | BRAND

THIS CEMENT DOES X MEET SPECIFICATION REQUIREMENTS

SAMPLE NO.	1							
SiO_2, %	22.5							
Al_2O_3, %	4.3							
Fe_2O_3, %	3.5							
MgO, %	2.9							
SO_3, %	2.0							
LOSS ON IGNITION, %	1.2							
ALKALIES-TOTAL AS Na_2O, %	0.45							
Na_2O, %	0.06							
K_2O, %	0.59							
INSOLUBLE RESIDUE, %	0.35							
CaO, %	62.8							
C_3S, %	45							
C_3A, %	6							
C_2S, %	30							
$C_3A + C_3S$, %	51							
C_4AF, %	11							
$C_4AF + 2\ C_3A$, %	22							
HEAT OF HYDRATION, 7D, CAL/G	67							
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A P)	3320							
AIR CONTENT, %	8.0							
COMP. STRENGTH, 3 D, PSI	1890							
COMP. STRENGTH, 7 D, PSI	2590							
COMP. STRENGTH, D, PSI								
FALSE SET-PEN, F I, %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.08							
INITIAL SET, HR/MIN	3:15							
FINAL SET, HR/MIN	5:20							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS 441-S707.19SC41

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Table 3

Cement Properties, Round 2

TO		FROM CORPS OF ENGINEERS U.S. ARMY
Structures Laboratory Research Group ATTN: Tony Liu Vicksburg, MS 39180	**REPORT OF TESTS OF PORTLAND CEMENT** RC-847	Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO. WES-609-79	BIN NO. 5	WT REPRESENTED	DATE 14 Jan 80
SPECIFICATION SS-C-1960/3, Type II, LA, HH		DATE SAMPLED 19 Dec 79	
COMPANY Citadel	LOCATION Birmingham, AL		BRAND
THIS CEMENT DOES X MEET SPECIFICATION REQUIREMENTS			

SAMPLE NO.	1		
SiO_2, %	22.1		
Al_2O_3, %	4.7		
Fe_2O_3, %	4.2		
MgO, %	4.3		
SO_3, %	1.7		
LOSS ON IGNITION, %	1.0		
ALKALIES-TOTAL AS Na_2O, %	0.48		
Na_2O, %	0.14		
K_2O, %	0.51		
INSOLUBLE RESIDUE, %	0.23		
CaO, %	61.5		
C_3S, %	41		
C_3A, %	5		
C_2S, %	33		
$C_3A + C_3S$, %	46		
C_4AF, %	13		
$C_4AF + 2\,C_3A$, %	23		
HEAT OF HYDRATION, 7D, CAL/G	66		
HEAT OF HYDRATION, 28D, CAL/G			
SURFACE AREA, SQ CM/G (A.P.)	3790		
AIR CONTENT, %	7.3		
COMP STRENGTH, 1 D PSI	1080		
COMP STRENGTH, 3 D PSI	1980		
COMP STRENGTH, 7 D PSI	2720	COMP. STRENGTH 28 D, PSI	4970
FALSE SET-PEN, F			
SAMPLE NO.	1		
AUTOCLAVE EXP, %	0.04		
INITIAL SET, HR/MIN	2:20		
FINAL SET, HR/MIN	4:45		
SAMPLE NO.			
AUTOCLAVE EXP			
INITIAL SET, HR/MIN			
FINAL SET, HR/MIN			

REMARKS

Job #483-SC04.10SC21

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Group

ENG FORM 4086-R

Table 4

Pozzolan Properties

LABORATORY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	**REPORT OF TESTS ON POZZOLAN** SS-C-1960/5 AD-590	REPORT NO WES-319F-79 SHEET 1 OF 1 DATE 16 July 79 6 August 79

CLASS (F) N — KIND OF POZZOLAN Fly Ash

SOURCE Williams Bros., Atlanta, GA — BRAND

TEST RESULTS OF THIS SAMPLE LOT X COMPLY ☐ DO NOT COMPLY WITH SPECIFICATION LIMITS SEE REMARKS

FOR USE AT

CONTRACT NO

DISTRICT(S)

SAMPLED BY Structures Branch — DATE SAMPLED 2 July 79

CAR NO — BIN NO

FIELD SAMPLE NO — LAB SAMPLE NO

DATE RECEIVED 2 July 79 — LAB JOB NO

TESTED BY Cem & Pozz Testing Branch — CHECKED BY

TESTS ON COMPOSITE OF THE 100-TON SAMPLES LISTED BELOW

$SiO_2 + Al_2O_3 + Fe_2O_3$ %	MgO %	SO_3 %	Available Alkalies %	Pozzolan Strength % Control	Increase in Shrinkage % (b)	Autoclave Expansion %	Reduction in Expansion % (b)
REQUIREMENTS							
MIN 70.0	MAX 5.0	MAX 4.0	MAX 1.5	MIN 75	MAX [illegible]	MAX [illegible]50	MIN 75
TEST RESULTS							
88	1.3	0.7	* 0.65	* 91		0.03	

TESTS ON SAMPLES REPRESENTING 100 TONS OR LESS

Sample No	Moisture Content %	Loss on Ignition %	Fineness 325 Mesh Sieve % Retained	% pts var from avg prev 10	Lime Pozzolan Strength psi	Water Requirement % of Control	Specific Gravity	Sp Gr Variation from Average of Preceding 10
REQUIREMENTS								
—	MAX 3.0	MAX 10.0 (N) 6.0 (F)	MAX 34	MAX 5	MIN 900	MAX 105	—	MAX 5
TEST RESULTS								
1	0.5	2.0	21		1120	97	2.43	
AVERAGE								

(a) APPLICABLE ONLY TO CLASS N — LABORATORY CEMENT USED Alpha, Birmingham, AL, WES-216-79

(b) OPTIONAL REQUIREMENT — LABORATORY LIME USED Chemstone

REMARKS Meets 7 day specification requirements. *28 day test report

441-S920.19SC42

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

NOTE: THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT

ENG FORM NO 6000 R
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Table 5

Mixture Proportions, Mixture A

REPORT OF SELECTION OF CONCRETE MIXTURE PROPORTIONS (CRD-C 3)

PROJECT NAME	SYMBOL / SERIAL NO	DATE
CONCRETE REQUIRED FOR		MIXTURE NO A

MATERIALS

PORTLAND CEMENT, SS-C-192	POZZOLON OR OTHER CEMENT	AIR ENT ADMIXTURE
TYPE II ADDITIONS	TYPE	TYPE NVR
BRAND AND MILL	SOURCE	AMOUNT AEA-965

FINE AGGREGATE	COARSE AGGREGATE
TYPE Natural	TYPE Natural SIZE 1-1/2
SOURCE Amyx Sand & Gravel Co., Jena, LA	SOURCE Amyx Sand & Gravel Co., Jena, LA

MATERIALS	SAMPLE SERIAL NO	SIZE RANGE	COARSE AGGR %	BULK SP GR SSD	ABSORP %
PORTLAND CEMENT *	RC-586/RC-847			3.15	
*					
*					
FINE AGGREGATE	NO-57 S-3(2)	No. 4 - 200		2.61	0.7
COARSE AGGREGATE (A)	NO-57 G-3(2)	No. 4 - 3/4 in.	30	2.54	1.5
COARSE AGGREGATE (B)	NO-57 G-3(2)	3/4 - 1-1/2 in.	70	2.54	1.1
COARSE AGGREGATE (C)					
COARSE AGGREGATE (D)					

MIXTURE DATA / SPECIMEN DATA

MATERIALS	MIX BY WEIGHT	S.S.D. WEIGHTS ONE CU YD BATCH (LB)	SOLID VOL ONE CU YD (CU FT)	CYLINDERS NO	CYLINDERS AGE	CYLINDERS PSI	BEAMS NO	BEAMS AGE	BEAMS PSI
PORTLAND CEMENT	1.00	450.0	2.289						
*									
*									
FINE AGGREGATE	2.44	1093.9	6.717						
COARSE AGGREGATE (A)	1.38	619.9	3.911						
COARSE AGGREGATE (B)	3.21	1446.6	9.127						
COARSE AGGREGATE (C)									
COARSE AGGREGATE (D)									
WATER	0.50	225.0	3.606						
AIR (5%)			1.350						
TOTAL		3835.4	27.000						

W/C (WT) 0.50	S/A, % VOLUME 34
SLUMP (IN)[4] 2-1/4	THEO UNIT WT (LB CU FT) 142.1
BLEEDING (%)[2]	ACTUAL UNIT WT (LB CU FT) 142.2
AIR CONTENT (%)[3] 4.5	THEO CEMENT FACT (LB CU YD)
AIR CONTENT (%)[4]	ACTUAL CEMENT FACT (LB CU YD) 450.0

1 Calculated on the basis of
2 Expressed as the percentage of mixing water separating from the concrete when tested by CRD-C 9
3 In the entire batch as mixed
4 In that portion of the concrete containing aggregate smaller than the 1-1/2-in. sieve

** For "other cement," pozzolan, second size of fine aggregate, as may be required*

REMARKS (Condition of mix, workability, plasticity, bleeding, etc)

*RC-586, Round 1 of tests
RC-847, Round 2 of tests

Table 6

Mixture Proportions, Mixture B

REPORT OF SELECTION OF CONCRETE MIXTURE PROPORTIONS (CRD-C 3)

PROJECT NAME	SYMBOL / SERIAL NO	DATE
CONCRETE REQUIRED FOR		MIXTURE NO B

MATERIALS

PORTLAND CEMENT, SS-C-192	POZZOLAN OR OTHER CEMENT	AIR-ENT. ADMIXTURE
TYPE II ADDITIONS	TYPE Fly Ash	TYPE NVR
BRAND AND MILL	SOURCE AD-590	AMOUNT AEA-965

FINE AGGREGATE	COARSE AGGREGATE
TYPE Natural	TYPE Natural SIZE 1-1/2
SOURCE Amyx Sand & Gravel Co., Jena, LA	SOURCE Amyx Sand & Gravel Co., Jena, LA

MATERIALS	SAMPLE SERIAL NO	SIZE RANGE	COARSE AGGR %	BULK SP GR SSD	ABSORP %
PORTLAND CEMENT *	RC-586/RC-847			3.15	
Fly Ash	AD-590			2.43	
*					
FINE AGGREGATE	NO-57 S-3(2)	No. 4 - 200		2.61	0.7
COARSE AGGREGATE (A)	NO-57 G-3(2)	No. 4 - 3/4 in.	30	2.54	1.5
COARSE AGGREGATE (B)	NO-57 G-3(2)	3/4 - 1-1/2 in.	70	2.54	1.1
COARSE AGGREGATE (C)					
COARSE AGGREGATE (D)					

MIXTURE DATA / SPECIMEN DATA

MATERIALS	MIX BY WEIGHT	S.S.D. WEIGHTS ONE CU YD BATCH (LB)	SOLID VOL ONE CU YD (CU FT)	CYLINDERS NO	AGE	PSI	BEAMS NO	AGE	PSI
PORTLAND CEMENT	1.00	337.5	1.717						
Fly Ash		86.7	0.572						
*									
FINE AGGREGATE		1093.9	6.717						
COARSE AGGREGATE (A)		619.9	3.911						
COARSE AGGREGATE (B)		1446.6	9.127						
COARSE AGGREGATE (C)									
COARSE AGGREGATE (D)									
WATER		225.0	3.606						
AIR (5%)			1.350						
TOTAL		3809.6	27.000						

W/C (WT) 0.53	S/A % VOLUME 34
SLUMP (IN) 2-1/2	THEO. UNIT WT (LB CU FT) 141.1
BLEEDING (%)	ACTUAL UNIT WT (LB CU FT) 147.4
AIR CONTENT (%) 4.3	THEO. CEMENT FACT (LB CU YD)
AIR CONTENT (%)	ACTUAL CEMENT FACT (LB CU YD) 424.2

1 Calculated on the basis of
2 Expressed as the percentage of mixing water separating from the concrete when tested by CRD-C 9
3 In the entire batch as mixed
4 In that portion of the concrete containing aggregate smaller than the 1-1/2 in. sieve

* For "other cement," pozzolan, second size of fine aggregate, as may be required

REMARKS: Condition of mix, workability, plasticity, bleeding, etc.

*RC-586, Round 1 of tests
RC-847, Round 2 of tests

WES FORM NO. 1353, REV. MAR 1972

Table 7

Testing Program,

Ultimate Strain Capacity Tests

Beam	Age, days	Test
1	1	Rapid
2	3	Rapid
3	3	Slow
4	*	Rapid
5	7	Rapid
6	7	Slow
7	*	Rapid
8	28	Rapid
9	28	Slow
10	*	Rapid
11	90	Rapid

* Beams so marked were tested in rapid loading on the day the companion beam failed in slow loading.

Table 8

Detailed Data, Ultimate Strain

Capacity Tests, Mixture A, Round 1

Beam No.	Testing Age, days	Loading Rate	Stress Capacity,** psi	Strain Capacity,* millionths Compressive	Strain Capacity,* millionths Tensile
A1	1	40 psi/min	159	51	46
A2	3	40 psi/min	281	78	82
A3	3-136	25 psi/week	450	115 (112)†	131 (134)†
A4	136	40 psi/min	427	84	84
A5	7	40 psi/min	377	83	83
A6	7-155	25 psi/week	495	132 (130)†	147 (150)†
A7	155	40 psi/min	458	80	92
A8	28	40 psi/min	393	82	88
A9	28-162	25 psi/week	450	56†	NA††
A10	162	40 psi/min	395	77	97
A11	90	40 psi/min	380	83	72

* Extrapolated outside fiber strain at 90 percent of ultimate load.
** Determined at 90 percent of ultimate load.
† Value determined with neutral axis fixed at center of beam.
†† No readings; meter malfunctioned.

Table 9

Detailed Data, Ultimate Strain Capacity Tests, Mixture A, Round 2

Beam No.	Testing Age, days	Loading Rate	Stress Capacity,** psi	Strain Capacity,* millionths	
				Compressive	Tensile
2A1	1	40 psi/min	145	50	53
2A2	3	40 psi/min	255	71	78
2A3	3-108	25 psi/week	360	--†	154††
2A4	108	40 psi/min	442	84	94
2A5	7	40 psi/min	352	82	89
2A6	7-148	25 psi/week	473	--†	188††
2A7	148	40 psi/min	473	92	90
2A8	28	40 psi/min	350	74	80
2A9A	28-184	25 psi/week	518	--†	224††
2A10A	184	40 psi/min	475	89	102
2A9B	28-147	25 psi/week	405	--†	183††
2A10B	147	40 psi/min	427	84	85
2A11	90	40 psi/min	332‡	83	91

* Extrapolated outside fiber strain at 90 percent of ultimate load.
** Determined at 90 percent of ultimate load.
† No readings; meter malfunctioned.
†† Value determined with neutral axis fixed at center of beam.
‡ Reduced modulus based upon break outside middle third of beam.

Table 10

Detailed Data, Ultimate Strain Capacity Tests, Mixture B, Round 1

Beam No.	Testing Age, days	Loading Rate	Stress Capacity,** psi	Strain Capacity,* millionths Compressive	Strain Capacity,* millionths Tensile
B1	1	40 psi/min	81	41	39
B2	3	40 psi/min	206	52	53
B3	3-108	25 psi/week	360	123 (122)†	129 (129)†
B4	108	40 psi/min	411	80	82
B5	7	40 psi/min	246	67	70
B6	7-113	25 psi/week	360	127 (125)†	139 (141)†
B7	113	40 psi/min	458	85	89
B8	28	40 psi/min	323	80	79
B9††	28-134	25 psi/min	360	89 (93)†	67 (64)†
B10	134	40 psi/min	406	81	90
B11	90	40 psi/min	359	83	91

* Extrapolated outside fiber strain at 90 percent of ultimate load.
** Determined at 90 percent of ultimate load.
† Value determined with neutral axis fixed at center of beam.
†† Tensile strain capacity appears to be low due to possible meter malfunction.

Table 11

Detailed Data, Ultimate Strain Capacity Tests, Mixture B, Round 2

Beam No.	Testing Age, days	Loading Rate	Stress Capacity,** psi	Strain Capacity,* millionths Compressive	Tensile
2B1	1	40 psi/min	81	36	42
2B2	3	40 psi/min	175	61	63
2B3	3-73	25 psi/week	248	--†	143††
2B4	73	40 psi/min	347	75	78
2B5	7	40 psi/min	176	51	62
2B6	7-114	25 psi/week	360	--†	178††
2B7	114	40 psi/min	412	83	90
2B8	28	40 psi/min	317	70	82
2B9A	28-133	25 psi/week	338	--†	143††
2B10A	133	40 psi/min	392	79	93
2B9B	28-119	25 psi/week	315	--†	142††
2B10B	119	40 psi/min	395	82	85
2B11	90	40 psi/min	422	84	90

* Extrapolated outside fiber strain at 90 percent of ultimate load.
** Determined at 90 percent of ultimate load.
† No readings; meter malfunctioned.
†† Value determined with neutral axis fixed at center of beam.

Table 12

Summarized Data, Ultimate Strain Capacity Tests, Rapid Loading, Mixture A, Rounds 1 and 2

Age, Days	Beam	Stress Capacity,* psi	Average	Tensile Strain Capacity,** millionths	Average
1	A1	159	152	46	50
	2A1	145		53	
3	A2	281	268	82	80
	2A2	255		78	
7	A5	377	365	83	86
	2A5	352		89	
28	A8	393	372	88	84
	2A8	350		80	
90	A11	380	356	72	82
	2A11	332†		91	
108	2A4	442	NA	94	NA
136	A4	427	NA	84	NA
147	2A10B	427	NA	85	NA
148	2A7	473	NA	90	NA
155	A7	458	NA	92	NA
162	A10	395	NA	97	NA
184	2A10A	475	NA	102	NA

* Determined at 90 percent of ultimate load.
** Extrapolated outside fiber strain at 90 percent of ultimate load.
† Reduced modulus based upon break outside middle third of beam.

Table 11

Detailed Data, Ultimate Strain Capacity Tests, Mixture B, Round 2

Beam No.	Testing Age, days	Loading Rate	Stress Capacity,** psi	Strain Capacity,* millionths Compressive	Strain Capacity,* millionths Tensile
2B1	1	40 psi/min	81	36	42
2B2	3	40 psi/min	175	61	63
2B3	3-73	25 psi/week	248	--†	143††
2B4	73	40 psi/min	347	75	78
2B5	7	40 psi/min	176	51	62
2B6	7-114	25 psi/week	360	--†	178††
2B7	114	40 psi/min	412	83	90
2B8	28	40 psi/min	317	70	82
2B9A	28-133	25 psi/week	338	--†	143††
2B10A	133	40 psi/min	392	79	93
2B9B	28-119	25 psi/week	315	--†	142††
2B10B	119	40 psi/min	395	82	85
2B11	90	40 psi/min	422	84	90

* Extrapolated outside fiber strain at 90 percent of ultimate load.
** Determined at 90 percent of ultimate load.
† No readings; meter malfunctioned.
†† Value determined with neutral axis fixed at center of beam.

Table 13

Summarized Data, Ultimate Strain Capacity Tests,

Rapid Loading, Mixture B, Rounds 1 and 2

Age, Days	Beam	Stress Capacity,* psi	Average	Tensile Strain Capacity,** millionths	Average
1	B1	81	81	39	41
	2B1	81		42	
3	B2	206	191	53	58
	2B2	175		63	
7	B5	246	211	70	66
	2B5	176		62	
28	B8	323	320	79	81
	2B8	317		82	
73	2B4	347	NA	78	NA
90	B11	359	391	91	91
	2B11	422		90	
108	B4	411	NA	82	NA
113	B7	458	NA	89	NA
114	2B7	412	NA	90	NA
119	2B10B	395	NA	85	NA
133	2B10A	392	NA	93	NA
134	B10	406	NA	90	NA

* Determined at 90 percent of ultimate load.
** Extrapolated outside fiber strain at 90 percent of ultimate load.

Table 14

Summarized Data, Ultimate Strain Capacity Tests, Slow Loading, Mixtures A and B, Rounds 1 and 2

Age, Days	Beam	Stress Capacity,* psi	Average	Tensile Strain Capacity,** millionths	Average
			Mixture A		
3-136	A3	450	405	131 (134)†	144
3-108	2A3	360		154†	
7-155	A6	495	484	147 (150)†	169
7-148	2A6	473		188†	
28-162	A9	450	458	NA	204
28-184	2A9A	518		244†	
28-147	2A9B	405		183†	
			Mixture B		
3-108	B3	360	304	129 (129)†	136
3-73	2B3	248		143†	
7-113	B6	360	360	139 (141)†	160
7-114	2B6	360		178†	
28-134	B9	360	338	67 (64)†,††	143
28-133	2B9A	338		143 †	
28-119	2B9B	315		142 †	

* Determined at 90 percent of ultimate load.
** Extrapolated outside fiber strain at 90 percent of ultimate load.
† Value determined with neutral axis fixed at center of beam.
†† Not included in average.

Table 15

Size Effects Data, Ultimate Strain Capacity Tests, Mixture A, Rounds 1 and 2

Testing Age, days	Beam No.	Beam Size, in.	Compressive Strength, psi	Stress Capacity,** psi	Strain Capacity,* millionths Compressive	Strain Capacity,* millionths Tensile
			Round 1			
3	C3	6 × 6 × 36	1720	288	70	87
3	C4	18 × 18 × 96	2200	264	NA†	66††
7	C1	6 × 6 × 36	3010	400	80	100
7	C2	18 × 18 × 96	2850	307	68	65
28	C5	6 × 6 × 36	4020	356	84	74
28	C6	18 × 18 × 96	3570	419	82	84
			Round 2‡			
3	2C7	6 × 6 × 36	1800	297	68	75
3	2C8	18 × 18 × 96	1800	258	64	67
7	2C1	6 × 6 × 36	2650	377	NA†	109
7	2C2	18 × 18 × 96	2650	294	68	74
28	2C3	6 × 6 × 36	4250	372	105	70
28	2C4	18 × 18 × 96	4250	378	69	74
90	2C5	6 × 6 × 36	4200‡‡	379	85	99
90	2C6	18 × 18 × 96	4200‡‡	351	71	76

* Outside fiber strain at 90 percent of ultimate load, extrapolated for 18- by 18- by 96-in. beams, measured for 6- by 6- by 36-in. beams.
** Determined at 90 percent of ultimate load.
† No reading; meter or gage malfunctioned.
†† Value determined with neutral axis fixed at center of beam.
‡ Values shown for 6- by 6- by 36-in. beams for Round 2 are averages of two specimens tested except for 2C1 for which data were obtained for only one specimen.
‡‡ Compressive strength of concrete in beams 2C5 and 2C6 was below average at 28 days.

Table 16

Size Effects Comparisons, Average Values for Beams of Sizes Indicated, Mixture A

	Age at Testing											
	3 Days			7 Days			28 Days			90 Days		
Beam Size	Compressive Strength, psi	Stress Capacity,** psi	Tensile Strain Capacity,* millionths	Compressive Strength, psi	Stress Capacity,** psi	Tensile Strain Capacity,* millionths	Compressive Strength, psi	Stress Capacity,** psi	Tensile Strain Capacity,* millionths	Compressive Strength, psi	Stress Capacity,** psi	Tensile Strain Capacity,* millionths
6 × 6 × 36 in.†	1760	293	81	2830	389	105	4140	364	72	4200	379	99
12 × 12 × 66 in.†	1820	268	80	2790	365	86	3740	372	84	4150	356	82
18 × 18 × 96 in.†	2000	261	67	2750	301	70	3910	399	79	4200	351	76
6 × 6 × 36 in.††			81			105			104			99
6 × 6 × 36 in.‡			84			107			106			101
12 × 12 × 66 in.‡			85			91			88			86
18 × 18 × 96 in.‡			75			77			85			82

* Outside fiber strain at 90 percent of ultimate load, extrapolated for 18- by 18- by 96-in. and 12- by 12- by 66-in. beams, measured for 6- by 6- by 36-in. beams.

** Determined at 90 percent of ultimate load.

† Strains as measured, no adjustments.

†† 28-day data point replaced by value which is a straight line interpolation between the 7-day and 90-day values.

‡ Adjusted strains in which strains due to dead loads of the beams have been added to measured strains to obtain total strain capacity.

Table 17

Compressive Strength and Splitting Tensile Strength Data, Mixture A, Rounds 1 and 2

Age, Days	Beam	Compressive Strength, psi	Average	Splitting Tensile Strength, psi	Average
1	A1	1000	1000	135	130
	2A1	990		120	
3	A2	1970	1820	240	220
	A3	1920		225	
	2A2	1790		205	
	2A3	1580		200	
7	A5	2880	2790	350	330
	A6	3040		335	
	2A5	2550		320	
	2A6	2680		315	
28	A8	3970	3740	420	365
	A9	3610		420	
	2A8	3130		305	
	2A9A	3870		300	
	2A9B	4130		390	
90	A11	4450	4150	420	420
	2A11	3840		420	
108	2A4	4540	NA	445	NA
136	A4	4830	NA	420	NA
147	2A10B	4850	NA	440	NA
148	2A7	5620	NA	505	NA
155	A7	5260	NA	405	NA
162	A10	4380	NA	475	NA
184	2A10A	6040	NA	475	NA

Table 18

Compressive Strength and Splitting Tensile Strength Data, Mixture B, Rounds 1 and 2

Age, Days	Beam	Compressive Strength, psi	Average	Splitting Tensile Strength, psi	Average
1	B1	600	570	80	70
	2B1	530		55	
3	B2	1220	1110	150	140
	B3	1180		155	
	2B2	1070		130	
	2B3	970		115	
7	B5	1830	1630	220	190
	B6	1910		225	
	2B5	1250		140	
	2B6	1520		180	
28	B8	3380	3260	345	320
	B9	3570		310	
	2B8	3400		315	
	2B9A	3070		335	
	2B9B	2880		295	
73	2B4	4070	NA	380	NA
90	B11	4520	4510	380	NA
	2B11	4500		NA	
108	B4	4390	NA	455	NA
113	B7	4920	NA	475	NA
114	2B7	4530	NA	350	NA
119	2B10B	4260	NA	395	NA
133	2B10A	4520	NA	455	NA
134	B10	5220	NA	380	NA

Table 19

Modulus of Elasticity and Poisson's

Ratio Data, Mixtures A and B, Rounds 1 and 2

Age, days	Beam	Modulus of Elasticity psi x 10^6	Average	Poisson's Ratio	Average
			Mixture A		
1	A1	2.90	2.68	0.14	0.18
	2A1	2.45		0.21	
3	A2	4.10	3.75	0.13	0.13
	2A2	3.40		0.12	
7	A5	4.60	4.23	0.17	0.19
	2A5	3.85		0.20	
28	A8	5.00	4.73	0.18	0.16
	2A8	4.45		0.14	
90	A11	5.50	5.15	0.17	0.14
	2A11	4.80		0.10	
			Mixture B		
1	B1	2.20	1.80	0.15	0.14
	2B1	1.40		0.13	
3	B2	3.40	2.93	0.12	0.12
	2B2	2.45		0.11	
7	B5	4.05	3.40	0.14	0.13
	2B5	2.75		0.11	
28	B8	5.20	4.88	0.13	0.15
	2B8	4.55		0.17	
90	B11	5.40	5.15	0.12	0.14
	2B11	4.90		0.16	

Table 20

Summary of Thermal

Properties, Mixtures A and B

Property	Mixture A	Mixture B
Thermal Diffusivity, ft^2/hr	0.042	0.045
Specific Heat, Btu/lb-^oF	0.22	0.22
Thermal Conductivity, Btu-ft/hr-ft^2-^oF	1.32	1.38
Adiabatic Temperature Rise (28 days), ^oF	70.07	64.66
Coefficient of Linear Expansion, millionths/^oF	7.0×10^{-6}	7.0×10^{-6}

Table 21

Adiabatic Temperature Rise Test

Data, Mixtures A and B

MIXTURE A AGE (DAYS)	MIXTURE A TEMP. RISE (DEG F)	MIXTURE B AGE (DAYS)	MIXTURE B TEMP.RISE (DEG F)
0.	0.	0.	0.
0.04	0.56	0.08	0.48
0.15	2.81	0.13	0.83
0.25	5.76	0.17	1.23
0.35	14.25	0.21	2.00
0.46	18.97	0.35	6.50
0.60	23.25	0.45	10.87
0.70	26.00	0.50	13.45
0.80	28.20	0.60	17.80
0.90	29.98	0.70	19.40
1.00	31.37	0.80	21.50
1.20	33.80	0.92	24.12
1.50	37.70	1.14	26.86
1.80	41.20	1.40	30.00
2.04	44.00	1.70	32.80
2.30	46.40	1.93	34.54
2.50	48.30	2.30	36.90
2.80	50.80	2.70	39.15
3.08	52.93	3.00	40.50
3.25	53.90	3.50	42.70
3.50	55.10	4.00	44.95
3.75	56.18	4.50	46.00
4.04	57.11	4.92	46.99
4.50	58.26	5.50	48.22
5.00	59.30	5.92	48.99
5.50	60.20	6.50	50.00
6.00	61.00	6.96	50.76
6.50	61.65	7.96	52.36
7.04	62.33	8.96	53.86
8.04	63.22	10.00	55.25
9.00	63.89	11.00	56.40
10.20	64.58	12.02	57.46
11.04	64.94	13.04	58.32
13.00	65.80	14.00	59.56
15.00	66.61	16.00	60.06
17.00	67.33	18.00	61.15
18.00	67.68	20.00	62.00
21.04	68.46	22.00	62.75
24.08	69.25	25.00	63.37
28.00	70.07	28.00	64.66
35.00	70.50	33.00	65.60
37.00	70.55	37.00	66.00

APPENDIX A: PETROGRAPHIC REPORT

Corps of Engineers, USAE Waterways Experiment Station	Petrographic Report	Concrete Laboratory P. O. Box 631 Vicksburg, Mississippi
Project Tests of Aggregate for New Orleans District		Date 15 April 1977 ADB

Samples

1. Pit run samples of gravel and sand were received on 28 December 1976 from the US Army Engineer District, New Orleans, for testing. The material is identified below:

Concrete Laboratory Serial No.	Field Data, New Orleans Identification
NO-57 G-3 NO-57 S-3	No. 1-3192-17A; sample No. LAS-1-1, from Amyx Gravel Co., Jena, La.

2. Since the total amount of gravel was insufficient for all tests, some physical tests were made on the same material that was used for the petrographic examination.

3. Each sample was from a source that had been tested before. The District identification number served to identify that source in the appropriate volume of Technical Memorandum No. 6-370.[1] There were no previous petrographic data for these materials.

4. The as-received grading of this sample did not conform to a Guide Specification grading, hence the composition was calculated by sieve sizes only. The total composition may be calculated once a satisfactory grading is established, or by using an assumed grading.

Test procedure

5. Gravel. A representative portion of each sieve size that made up 5 percent or more of the total sample was separated into lithologic types, using a stereoscopic microscope as needed. Particles were examined while dry and usually again while wet; occasional particles were broken and examined as powder immersion mounts with a polarizing microscope to assist in classification. The largest material was always examined regardless of the amount in the sieve fraction, as it is easier to establish the lithologic types using large material.

6. Sand. Representative portions of the sizes larger than 600 μm (No. 30 sieve) were immersed in water, and classified while using a stereoscopic microscope to examine the particles. Representative portions of the sizes smaller than 600 μm that amounted to 5 percent or more of the total sample were examined as powder immersion mounts with a polarizing microscope.

1. "Test Data - Concrete Aggregates in Continental United States," with periodic supplements, US Army Engineer Waterways Experiment Station, Vicksburg, Miss., Sep 1953.

7. All powder immersion mounts, whether of gravel or sand, were made using an oil of 1.544 refractive index, which permitted determination of chalcedonic chert by searching for chert particles with indices below 1.544, the upper index of chalcedonic chert.

8. Since the sizes smaller than 150 μm (No. 100 sieve) usually amounted to less than 5 percent of the total sand sample, their composition was usually assumed to be the same as the next larger size or was estimated by examination of a powder immersion mount.

Results

9. Gravel (NO-57 G-3). The sample was a brown chert gravel consisting largely of tabular to blocky particles with rounded edges. More of the particles were pyramidal or irregular in shape as size decreased.

a. Dense chert. The chert was dense, structureless rock.

b. Fractured chert. Similar to the dense chert except that the particles contain fractures; it is assumed that normal handling and or mixing procedures would cause these particles to separate along the fractures. Such separation can be significant if there is a substantial amount of fractured chert because the development of new surface area could affect the workability and water demand of concrete mixtures.

c. Vuggy chert. Similar to the dense chert, but with the particles characterized by surface reentrants so that the total surface area is greater than it would be for a particle of similar size without reentrants.

d. Porous chert. The porous chert particles are frequently pale colored grading to white and are more ellipsoidal in shape than the other varieties of chert. Such aggregate particles may be expected to form unsightly popouts on concrete surfaces when they are embedded close enough to a concrete surface and are frozen in a saturated condition. Some particles are porous throughout, while other particles contain some areas of porous rock. The areas of porous rock occur as scattered patches, as particle rims, or as particle interiors.

e. Quartz. The quartz particles tend to be light colored. The shape is tabular with rounded edges in the larger sizes and becomes ellipsoidal with decreasing particle size. Quartz increases with decreasing particle size (Table 1).

f. Miscellaneous. This category is composed of tan to red fine-grained sandstone and or quartzite particles, igneous rock particles, and pink to white feldspar particles. The sandy and the igneous rock particles are usually tabular or ellipsoidal in shape while the feldspars are blocky with sharp edges. The feldspar is usually found in the smaller particle sizes. Some of each of these types is weathered rock.

10. Sand (NO-57 S-3). The sand is dark yellowish orange (10 YR 6/6).[2] Its composition by size fractions is shown in Table 2. It is a typical natural sand with quartz increasing and chert decreasing as the particle size decreases. A description of the sand constituents follows:

a. Quartz. The particles are mostly light colored and translucent in the largest size. As size decreases the particles become predominantly clear transparent quartz. The shape is blocky with rounded edges or ellipsoidal.

b. Chert. These are usually dense chert particles with blocky shapes and rounded edges. Some of the chert is chalcedonic.

c. Feldspar. This material was separated from the miscellaneous category since it amounts to from 6 to 14 percent of the different sizes (Table 2). It is like the feldspar particles in the gravel. Most of the particles are orthoclase but some microcline and plagioclase particles were seen.

d. Miscellaneous. This material amounts to 10 percent of the 150-μm (No. 100) size and less than 5 percent of the other sizes (Table 2). It is a mixture of sandstone, quartzite, igneous rocks, various heavy minerals, and opaque rock particles.

Discussion

11. Chalcedonic chert is present in the sand and is assumed to be present in the gravel since both samples are from the same source. Thus, the possibility of deleterious alkali-silica reaction exists if either or both of these materials is used as concrete aggregate, and appropriate control measures should be specified. The control measures possible include use of low-alkali cement or the addition to a medium-alkali cement of an adequate amount of a suitable pozzolan. If this second course is chosen, tests of the aggregate, job cement, and job pozzolan should be made according to CRD-C 123.

---

2. The Rock-Color Chart Committee, National Research Council, Rock-Color Chart, Washington, DC, 1963.

Table 1

Composition of Pit Run Gravel NO-57 G-3

from Amyx Gravel Co., Jena, La.

Constituents	Composition of Sizes Indicated Below, Percent* 25 mm (1 in.)	19 mm (3/4 in.)	12.5 mm (1/2 in.)	9.5 mm (3/8 in.)	4.75 mm (No. 4)
Chert					
dense	81	87	82		
fractured	--	2	1	78	64
vuggy	2	2	--		
porous	15	9	7	7	4
Quartz	2	--	6	13	32
Miscellaneous**	--	--	4	2	--
Total	100	100	100	100	100

Table 2

Composition of Pit Run Sand NO-57 S-3

from Amyx Gravel Co., Jena, La.

Constituents	Composition of Sizes Indicated Below, Percent* 2.36 mm (No. 8)	1.18 mm (No. 16)	600 μm (No. 30)	300 μm (No. 50)	150 μm (No. 100)
Quartz	44	62	87	84	69
Chert	38	22	6	6	13
Feldspar	14	14	6	6	8
Miscellaneous**	4	2	1	4	10
Total	100	100	100	100	100

* Based on examination of 300 or more particles when possible. The 25-, 19-, and 9.5-mm sizes consisted of 46, 134, and 280 particles, respectively.

** Sandstone or quartzite, igneous rocks, and feldspar. Some of each type is weathered. The sand also includes mica, and unidentified heavy minerals and opaque particles. Feldspar was counted separately in the sand.

APPENDIX B: COMPUTER PROGRAM LISTING

```
C
C **** PROGRAM STRAIN CALCULATIONS
C
C       TERENCE C. HOLLAND
C       WATERWAYS EXPERIMENT STATION
C       JANUARY, 1981
C
C **** THIS PROGRAM IS INTENDED FOR USE WITH TEST
C       METHOD CRD-C 71, "STANDARD TEST METHOD FOR
C       ULTIMATE TENSILE STRAIN CAPACITY OF
C       CONCRETE."  THE PROGRAM REDUCES DATA OBTAINED
C       FROM CARLSON INTERNAL STRAIN METERS FOR
C       EITHER THE SLOW OR RAPID LOADING CASES.  AN
C       OPTIONAL REGRESSION ANALYSIS IS ALSO AVAIL-
C       ABLE TO ALLOW STRAIN CAPACITY DETERMINATION AT
C       90 PERCENT OF THE MODULUS OF RUPTURE.  ADDITIONAL
C       DETAILS ARE AVAILABLE FROM THE AUTHOR.
C
C **** ESSENTIAL VARIABLES ARE DEFINED WHEN FIRST USED
C
      CHARACTER IDENT*60, LABEL*25, FN*8, AFN*16,
&      SYFLAG*5, AXFLAG*5, LOFLAG*5, DAFLAG*5
      DIMENSION RO(2), TR(2), TC(2), CAL(2),
&      VOLTS(200), CALSTR(200), RESIS(2,200),
&      RATIO(2,200), TEMPO(2,2), RATO(2,2), TEMP(2,200),
&      DELTMP(2), DELRAT(2), STRIND(2,200), STRACT(2,200),
&      LABEL(200), EXTSTR(2,200), START(2), NUM(2),
&      SUMX(2), SUMX2(2), SUMXY(2), SUMY(2),
&      SUMY2(2), B(2), R(2), STRAN9(2), BUFF(380), MN(2)
      REAL LOAD(200), NUAXIS(200), M(2), LEN
      INTEGER DATE(200,3), DATE1, DATE2, DATE3,
&      LO(2), HI(2), ERFLAG
C
C **** SET USER CONTROLLED OPTIONS
C
C       AXFLAG CONTROLS NEUTRAL AXIS
C          AXFLAG="CALCU", CALCULATES
C          AXFLAG="FIXED", USES MID DEPTH
C       SYFLAG CONTROLS SYSTEM SELECTION
C          SYFLAG="TIMES", TIMESHARE (INTERACTIVE)
C             * SINGLE BEAM
C             * SELECT DATA PRINT
C             * SELECT REGRESSION
C          SYFLAG="BATCH", BATCH VIA CARDIN (NOT INTERACTIVE)
C             * SINGLE OR MULTIPLE BEAMS
C             * PRINTS ALL DATA
C             * NO REGRESSION
C
      AXFLAG = "FIXED"
      SYFLAG = "BATCH"
```

```
C
C **** THIS SECTION CONTROLS INPUT IN BATCH MODE
C
C      A FILE NAMED "LIST" MUST CONTAIN NAMES OF
C      DATA FILES, ONE DATA FILE IS REQUIRED FOR EACH BEAM.
C
C      FN = FILENAME
C      AFN = MODIFIED FILE NAME "ROCC45/FN;"
C      BUFF = BUFFER FOR ATTACH
C
      IF (SYFLAG.EQ."TIMES") GO TO 130
C
      CALL ATTACH(21, "ROCC45/LIST;", 1, 0, , BUFF)
  100 READ (21,110,END = 960) FN
  110 FORMAT (A8)
      ENCODE (AFN,120) FN
  120 FORMAT ("ROCC45/", A8, ";")
      CALL ATTACH(20, AFN, 1, 0, , BUFF)
C
C **** INPUT BEAM CONSTANTS AND DATA FOR BOTH METERS
C
C      LOFLAG DETERMINES TYPE OF LOADING
C         LOFLAG="RAPID", RAPID LOAD
C         LOFLAG="SLOW ", SLOW LOAD
C
  130 READ (20,140) LOFLAG
      IF (LOFLAG.EQ."RAPID") GO TO 150
      IF (LOFLAG.EQ."SLOW ") GO TO 150
      ERFLAG = 100
      GO TO 940
  140 FORMAT (A5)
  150 READ (20,160) IDENT
      READ (20,170) SIZE, SPAN, LEN
  160 FORMAT (A60)
      READ (20,170) MN(1), RO(1), TR(1), TC(1), CAL(1)
      READ (20,170) MN(2), RO(2), TR(2), TC(2), CAL(2)
  170 FORMAT (V)
C
C **** INPUT DATA LEVEL, INITIALIZE COUNTERS, AND
C      TRANSFER TO CORRECT DATA INPUT
C
C      DAFLAG DETERMINES AMOUNT OF DATA
C         DAFLAG="COMPL", COMPLETE DATA
C         DAFLAG="ABBRE", ABBREVIATED DATA (NONE PRIOR TO LOADING)
C
      READ (20,140) DAFLAG
      I = 1
      IF (DAFLAG.EQ."COMPL") GO TO 190
      IF (DAFLAG.EQ."ABBRE") GO TO 180
      ERFLAG = 200
```

```
           GO TO 940
C
      180  IFLAG1 = 0
           IFLAG2 = 0
           GO TO 230
C
C **** INPUT DATA FOR PHASE PRIOR TO LOADING
C       (COMPLETE DATA ONLY)
C
      190  READ (20,200) (DATE(I,J), J = 1, 3), RESIS(1,I),
&           RATIO(1,I), RESIS(2,I), RATIO(2,I), LABEL(I)
      200  FORMAT (I2, 2I3, F6.2, F7.2, F6.2, F7.2, A25)
           VOLTS(I) = 0.
           LOAD(I) = 0.0
           IF (DATE(I,1).EQ.55) GO TO 210
           IF (DATE(I,1).EQ.77) GO TO 220
           I = I + 1
           GO TO 190
C
      210  IFLAG1 = I - 1
           GO TO 190
C
      220  IFLAG2 = I - 1
C
C **** BASED ON LOADING RATE TRANSFER TO INPUT
C       LOADING DATA
C
      230  IF (LOFLAG.EQ."RAPID") GO TO 240
           IF (LOFLAG.EQ."SLOW ") GO TO 270
C
C **** INPUT DATA FOR LOADING PHASE (RAPID LOAD)
C
      240  READ (20,170) DATE1, DATE2, DATE3
      250  READ (20,260,END = 290) VOLTS(I), RESIS(1,I),
&           RATIO(1,I), RESIS(2,I), RATIO(2,I), LABEL(I)
      260  FORMAT (F6.4, F6.2, F7.2, F6.2, F7.2, A25)
           DATE(I,1) = DATE1
           DATE(I,2) = DATE2
           DATE(I,3) = DATE3
           I = I + 1
           GO TO 250
C
C **** INPUT DATA FOR LOADING PHASE (SLOW LOAD)
C
      270  READ (20,280,END = 290) (DATE(I,J), J = 1,
&           3), LOAD(I), RESIS(1,I), RATIO(1,I), RESIS(2,I),
&           RATIO(2,I), LABEL(I)
      280  FORMAT (I2, 2I3, F7.0, F6.2, F7.2, F6.2, F7.2, A25)
           I = I + 1
           GO TO 270
```

```
C
C **** SET COUNTER FOR NUMBER OF DATA POINTS.
C      TRANSFER TO CALCULATE LOADS AND STRESSES
C
  290 IFLAG3 = I - 1
      IF (LOFLAG.EQ."RAPID") GO TO 300
      IF (LOFLAG.EQ."SLOW ") GO TO 320
C
C **** CALCULATE LOADS AND STRESSES.
C      NOTE - CALSTR IS A FUNCTION OF BEAM SIZE.
C
C ++++ RAPID
C
  300 DO 310 J = 1, IFLAG3
      LOAD(J) = VOLTS(J) * 50000.
      CALSTR(J) = (3. * LOAD(J) * SPAN) / SIZE ** 3
  310 CONTINUE
      GO TO 340
C
C ++++ SLOW
C
  320 DO 330 J = 1, IFLAG3
      CALSTR(J) = (3. * LOAD(J) * SPAN) / SIZE ** 3
  330 CONTINUE
      GO TO 340
C
C **** BASED ON DATA LEVEL, SET BASE VALUES FOR
C      TEMP AND RATIO. SET START/STOP POINTS
C      FOR CALCULATIONS.
C
  340 IF (DAFLAG.EQ."COMPL") GO TO 350
      IF (DAFLAG.EQ."ABBRE") GO TO 370
C
C ++++ COMPLETE DATA
C
  350 N1 = IFLAG1 + 1
      N2 = IFLAG2 + 1
      DO 360 K = 1, 2
      TEMPO(K,1) = (RESIS(K,N1) - RO(K)) * TR(K)
      TEMPO(K,2) = (RESIS(K,N2) - RO(K)) * TR(K)
      RATO(K,1) = RATIO(K,N1)
      RATO(K,2) = RATIO(K,N2)
  360 CONTINUE
C
      JFLAG = 0
      ISTART = IFLAG1 + 2
      ISTOP = IFLAG2
      J2 = 1
      GO TO 390
C
```

```
C ++++ ABBREVIATED DATA
C
  370 DO 380 K = 1, 2
      TEMPO(K,2) = (RESIS(K,1) - RO(K)) * TR(K)
      RATO(K,2) = RATIO(K,1)
  380 CONTINUE
C
      ISTART = 2
      ISTOP = IFLAG3
      JFLAG = 1
      J2 = 2
      GO TO 390
C
C **** PERFORM CALCULATIONS
C
C       J COUNTS DATA POINTS
C       J1 COUNTS METER
C          J1=1, COMPRESSION METER
C          J1=2, TENSION METER
C       J2 COUNTS LOADING PHASE
C          J2=1, PRIOR TO LOADING PHASE
C          J2=2, LOADING PHASE
C       JFLAG CAUSES REPEAT FOR SECOND
C       PHASE (COMPLETE DATA ONLY)
C
  390 CONTINUE
      IF (AXFLAG.EQ."FIXED") GO TO 400
C
      A1 = SIZE - 3.0
      A2 = (SIZE - 1.5) / A1
      A3 = 1.5 / A1
C
  400 DO 430 J = ISTART, ISTOP
      DO 410 J1 = 1, 2
      TEMP(J1,J) = (RESIS(J1,J) - RO(J1)) * TR(J1)
      DELTMP(J1) = TEMP(J1,J) - TEMPO(J1,J2)
      DELRAT(J1) = RATIO(J1,J) - RATO(J1,J2)
      STRIND(J1,J) = DELRAT(J1) * CAL(J1) * 100.
      STRACT(J1,J) = STRIND(J1,J) + DELTMP(J1) *
&       TC(J1) - DELTMP(J1) * 5.5
  410 CONTINUE
C
      IF (J2.EQ.1) GO TO 430
      IF (AXFLAG.EQ."FIXED") GO TO 420
      SUM = ABS(STRACT(1,J)) + ABS(STRACT(2,J))
      EXTSTR(1,J) = STRACT(1,J) / ABS(STRACT(1,J)) *
&      (ABS(STRACT(1,J)) + SUM * A3)
      EXTSTR(2,J) = (SUM * (A2) - ABS(STRACT(1,J))) *
&      (STRACT(2,J) / ABS(STRACT(2,J)))
      NUAXIS(J) = ((A1*ABS(STRACT(2,J))) / SUM) + 1.5
```

```
      GO TO 430
C
  420 EXTSTR(1,J) = (SIZE / (SIZE - 3.0)) * STRACT(1,J)
      EXTSTR(2,J) = (SIZE / (SIZE - 3.0)) * STRACT(2,J)
      NUAXIS(J) =  - 6.0
C
  430 CONTINUE
C
      IF (JFLAG.EQ.1) GO TO 440
      JFLAG = 1
      ISTART = IFLAG2 + 2
      ISTOP = IFLAG3
      J2 = 2
      GO TO 400
C
C **** DETERMINE IF DATA OUTPUT IS DESIRED
C       (INTERACTIVE ONLY)
C
  440 CONTINUE
      IF (SYFLAG.EQ."BATCH") GO TO 460
      PRINT 450
  450 FORMAT ( // , "IF COMPLETE DATA NOT DESIRED ENTER 1")
      READ (05,170) J6
      IF (J6.EQ.1) GO TO 690
      GO TO 460
C
C **** OUTPUT DATA DESCRIBING METERS AND ALL RAW DATA
C
  460 CONTINUE
      PRINT 470, IDENT
  470 FORMAT ( // , A60,  // )
      PRINT 480, MN(1)
      PRINT 500, R0(1), TR(1), TC(1), CAL(1)
      PRINT 490, MN(2)
      PRINT 500, R0(2), TR(2), TC(2), CAL(2)
  480 FORMAT ("COMP. METER NO.  ", I4)
  490 FORMAT ("TENS. METER NO.  ", I4)
  500 FORMAT (7X, "METER RESIS (R0) (OHMS)  =  ",
&      F6.2,  / , 7X, "TEMP/RESIS (TR) (DEG F/OHM)  =  ",
&      F6.2,  / , 7X, "TEMP CORRECTION (TC) (UIN/IN/DEG F)  =  ",
&      F6.2,  / , 7X, "CAL CONST (CAL) (UIN/IN/0.01% RATIO)  =  "
&     , F6.2)
      PRINT 510
  510 FORMAT ( / , "RAW DATA",  // )
C
      IF (LOFLAG.EQ."SLOW ") GO TO 550
C
C ++++ RAPID
C
      PRINT 520
```

```
  520 FORMAT (2X, "DATE", 5X, "VOLTS", 3X, "COMPRESSION",
&       5X, "TENSION", 12X, "REMARKS",  / , 19X,
&      "RESIS RATIO", 3X, "RESIS RATIO",  // )
      DO 540 K = 1, IFLAG3
      PRINT 530, (DATE(K,J), J = 1, 3), VOLTS(K),
&      RESIS(1,K), RATIO(1,K), RESIS(2,K), RATIO(2,K), LABEL(K)
  530 FORMAT (3I3, F8.4, 4F7.2, A25)
  540 CONTINUE
      GO TO 590
C
C ++++ SLOW
C
  550 PRINT 560
  560 FORMAT (2X, "DATE", 5X, "LOAD,", 3X, "COMPRESSION",
&       5X, "TENSION", 12X, "REMARKS",  / , 11X,
&      "LBS", 5X, "RESIS RATIO", 3X, "RESIS RATIO",  // )
      DO 580 K = 1, IFLAG3
      PRINT 570, (DATE(K,J), J = 1, 3), LOAD(K),
&      RESIS(1,K), RATIO(1,K), RESIS(2,K), RATIO(2,K), LABEL(K)
  570 FORMAT (3I3, F8.0, 4F7.2, A25)
  580 CONTINUE
C
C **** IF COMPLETE DATA, OUTPUT DATA FOR PRIOR
C       TO LOADING PHASE
C
  590 IF (DAFLAG.EQ."ABBRE") GO TO 640
C
      PRINT 600, IDENT
  600 FORMAT ( // , A60,  // , "REDUCED DATA == PRIOR TO LOADING"
&      ,  // )
      PRINT 610
  610 FORMAT (1X, "LOAD,    CALC", 6X, "COMPRESSION METER",
&       9X, "TENSION METER",  / , 2X, "LBS     STRESS,",
&       5X, "TEMP,  ACTSTN,", 12X, "TEMP,  ACTSTN,",
&        / , 11X, "PSI", 8X, "DEG F  UIN/IN", 12X,
&      " DEG F  UIN/IN",  // )
      ISTART = IFLAG1 + 2
      DO 630 L = ISTART, IFLAG2
      PRINT 620, LOAD(L), CALSTR(L), TEMP(1,L),
&      STRACT(1,L), TEMP(2,L), STRACT(2,L)
  620 FORMAT (2F7.0, 4X, 2F8.1, 10X, 2F8.1)
  630 CONTINUE
      GO TO 640
C
C **** OUTPUT DATA FOR LOADING PHASE
C
  640 CONTINUE
      PRINT 650, IDENT
  650 FORMAT ( // , A60,  // , "REDUCED DATA == DURING LOADING",
&        // )
```

```
      PRINT 660
  660 FORMAT (1X, "LOAD,    CALC", 6X, "COMPRESSION METER",
&      9X, "TENSION METER", 7X, "NU-AX",  / , 2X,
&      "LBS     STRESS, TEMP,", 2X, "ACSTN,  EXSTN,"
&     , "   TEMP,  ACSTN,  EXSTN,   ABOVE",  / ,
&      11X, "PSI", 4X, "DEG F  UIN/IN  UIN/IN  "
&     , " DEG F  UIN/IN  UIN/IN BASE, IN",  // )
      ISTART = IFLAG2 + 2
      DO 680 L = ISTART, IFLAG3
      PRINT 670, LOAD(L), CALSTR(L), TEMP(1,L),
&      STRACT(1,L), EXTSTR(1,L), TEMP(2,L), STRACT(2,L),
&      EXTSTR(2,L), NUAXIS(L)
  670 FORMAT (2F7.0, 7F8.1)
  680 CONTINUE
C
C **** DETERMINE IF CURVE FIT IS DESIRED
C      (INTERACTIVE ONLY)
C
  690 CONTINUE
      IF (SYFLAG.EQ."BATCH") GO TO 920
      PRINT 700
  700 FORMAT ( // , " IF CURVE FIT IS DESIRED ENTER 1")
      READ (05,170) J5
      IF (J5.NE.1) GO TO 920
C
C **** ENTER NECESSARY DATA FROM TERMINAL
C
      PRINT 710
  710 FORMAT (" ENTER STARTING STRESS AND NUMBER"
&     , " OF POINTS FOR COMPRESSION FIT")
      READ (05,170) START(1), NUM(1)
      PRINT 720
  720 FORMAT (" ENTER STARTING STRESS AND NUMBER"
&     , " OF POINTS FOR TENSION FIT")
      READ (05,170) START(2), NUM(2)
      PRINT 730
  730 FORMAT (" ENTER FAILURE STRESS")
      READ (05,170) FLSTR
C
C **** DETERMINE START AND STOP POINTS FOR REGRESSION
C
      DO 760 J = 1, 2
      DO 740 I = ISTART, IFLAG3
      IF (ABS(START(J) - CALSTR(I)).LE.0.50) LO(J) = I
      IF (ABS(START(J) - CALSTR(I)).LE.0.50) GO TO 750
  740 CONTINUE
  750 HI(J) = LO(J) + NUM(J) - 1
  760 CONTINUE
C
C **** COMPUTE VARIABLES FOR REGRESSION ANALYSIS
```

```
C
      DO 780 K = 1, 2
      SUMX(K) = 0.0
      SUMX2(K) = 0.0
      SUMXY(K) = 0.0
      SUMY(K) = 0.0
      SUMY2(K) = 0.0
      L1 = LO(K)
      L2 = HI(K)
      DO 770 L = L1, L2
      SUMX(K) = SUMX(K) + CALSTR(L)
      SUMX2(K) = SUMX2(K) + CALSTR(L) ** 2
      SUMXY(K) = SUMXY(K) + CALSTR(L) * EXTSTR(K,L)
      SUMY2(K) = SUMY2(K) + EXTSTR(K,L) ** 2
      SUMY(K) = SUMY(K) + EXTSTR(K,L)
  770 CONTINUE
C
      DENOM = NUM(K) * SUMX2(K) - SUMX(K) ** 2
      M(K) = (NUM(K) * SUMXY(K) - SUMX(K) * SUMY(K)) / DENOM
      B(K) = (SUMY(K) * SUMX2(K) - SUMX(K) * SUMXY(K)) / DENOM
      R(K) = (NUM(K) * SUMXY(K) - SUMX(K) * SUMY(K)) /
&      (SQRT(DENOM) * (SQRT(NUM(K) * SUMY2(K) - SUMY(K) ** 2)))
  780 CONTINUE
C
C **** COMPUTE 90 PERCENT VALUES
C
      FLSTR9 = 0.9 * FLSTR
      DO 790 I = 1, 2
      STRAN9(I) = M(I) * FLSTR9 + B(I)
  790 CONTINUE
C
C **** OUTPUT DATA
C
      PRINT 470, IDENT
      IF (AXFLAG.EQ."CALCU") PRINT 840
      IF (AXFLAG.EQ."FIXED") PRINT 850
      DO 800 I = 1, 2
      IF (I.EQ.1) PRINT 810
      IF (I.EQ.2) PRINT 820
      I1 = LO(I)
      I2 = HI(I)
      PRINT 830, CALSTR(I1), EXTSTR(I,I1), CALSTR(I2),
&      EXTSTR(I,I2), M(I), B(I), R(I)
  800 CONTINUE
  810 FORMAT (" FOR COMPRESSION FIT == ")
  820 FORMAT (" FOR TENSION FIT == ")
  830 FORMAT (5X, "START", F6.0, 2X, "PSI,", F8.1,
&      2X, "UIN/IN",  / , 5X, "STOP ", F6.0, 2X,
&      "PSI,", F8.1, 2X"UIN/IN",  / , 5X, "M = ",
&      F6.3,  / , 5X, "B = ", F6.3,  / , 5X, "R = ", F6.3,  // )
```

```
 840 FORMAT ("FOLLOWING VALUES BASED ON CALCULATED NEUTRAL AXIS"
&        , / )
 850 FORMAT ("FOLLOWING VALUES BASED ON FIXED NEUTRAL AXIS",
&         / )
C
         PRINT 860
 860 FORMAT (" SUMMARY OF STRAIN CAPACITY TEST", )
         PRINT 470, IDENT
         PRINT 870, SIZE
 870 FORMAT (" BEAM SIZE, IN == ", F8.2)
         PRINT 880, LEN
 880 FORMAT (" BEAM LENGTH, IN == ", F8.2)
         PRINT 890, FLSTR
 890 FORMAT (" MODULUS OF RUPTURE, PSI == ", F8.0)
         PRINT 900, FLSTR9
 900 FORMAT (" 90 PERCENT OF MODULUS, PSI == ", F8.0)
         PRINT 910, STRAN9(1), STRAN9(2)
 910 FORMAT (" EXTREME FIBER STRAIN AT 90 PERCENT"
&        , " OF MODULUS, UIN/IN == ",  / , 5X, "COMPRESSION",
&         F8.1,  / , 5X, "TENSION", F8.1)
C
 920 CONTINUE
         IF (SYFLAG.EQ."TIMES") GO TO 960
         CALL DETACH(20, , )
         PRINT 930
 930 FORMAT ("1")
         GO TO 100
C
 940 PRINT 950, ERFLAG
 950 FORMAT (" ERROR FLAG = ", I5, "PROGRAM HALTED")
C
 960 CALL EXIT
         STOP
         END
```

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Holland, Terence C.
Determination of properties of concrete used in thermal studies for Lock and Dam No. 2, Red River Waterway / by Terence C. Holland, Tony C. Liu, Anthony A. Bombich (Structures Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1982.
62 p. in various pagings ; ill. ; 27 cm. -- (Miscellaneous paper ; SL-82-5)
Cover title.
"June 1982."
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1. Concrete--Testing. 2. Concrete--Thermal properties. 3. Concrete dams. 4. Red River (Tex.-La.) I. Liu, Tony C. II. Bombich, Anthony A. III. United States. Army. Corps of Engineers. St. Louis District. IV. United

Holland, Terence C.
Determination of properties of concrete used in : ... 1982.
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States. Army. Corps of Engineers. New Orleans District. V. U.S. Army Engineer Waterways Experiment Station. Structures Laboratory. VI. Title VII. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; SL-82-5.
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